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SUPPLYING THE WORLD WITH NEWS.*

BY

MELVILLE E. STONE, LL.D.,
General Manager, The Associated Press, New York City, N. Y.

I HAVE had some doubt as to the precise propriety of my presence here to-night. This institution is given over to the technicalities of the Arts and Sciences. But, on reflection, I think I find some warrant for my intrusion. I am minded that you take your name from that great American, who was not only a notable diplomat, statesman, scientist, and philosopher, but was also, in his day, the Master Printer of the Colonies. And in this room you have, as if ordered for the occasion, side by side, Franklin's original apparatus for the study of electricity, and the imposing stone which he used in his printing office. It is also worthy of mention that another printer who for many years was a valued member of the institution, Mr. William Swain, one of the founders of the *Philadelphia Public Ledger*, was an active co-worker with Professor Morse in developing telegraphy and in fitting that great invention to ministry in the business of news gathering. So, in the words of Paul, I have "waxed confident by these bonds."

As you pick up your daily newspaper, issued to you for the smallest coin that is minted by the Government—filled as it is with a vast bulk of information gathered from every habitable

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spot on the globe—if you have anything like an inquisitive mind, your curiosity must be aroused. It must interest you to know how all this so-called "news," good and indifferent, important and trivial, from nearby places and from the uttermost parts, is collected, transmitted, and delivered to you at so small cost. Well, this I shall strive to tell you: not in an oration, nor even in a speech, but in a quiet, fireside talk.

Also, it may gratify you to remember that this business of systematic and comprehensive news-gathering is an American enterprise. It originated here, and here it has reached its most perfect development. The work began in the early days of the last century. Our Revolutionary War had closed and the Federal Government had been successfully established. But great things were happening abroad. Bonaparte, after his unparalleled career of victory, had pushed his conquering squadrons over the continent, had invaded Russia, and was on his way to Moscow. The hour was one pregnant of great possibilities for our infant republic. It was natural that at such a moment there should be an avid call for news from Europe.

It was then that Samuel Topliff, of Boston, entered the field. He took charge of the news-books of the Exchange Coffee House and began a career as a news-gatherer which lasted over thirty years and which, for zeal and efficiency, has rarely been equalled. With a small boat he ran into Boston harbor on the arrival of a European vessel, interviewed the captain, and rushed back to record this latest information in his news-books at the Coffee House. Thither merchants, and later newspaper reporters, repaired, and thus the news was distributed. To hurry this news into and through the country from city to city, fast pony expresses were introduced, carrier pigeons were trained, and rude semaphores, to wig-wag from hilltop to hilltop, were set up. Then, in time, the steamship supplanted the sailing craft, the railroad usurped the functions of the stage-coach and the expresses, and, finally, the electric telegraph displaced the pigeons and semaphores.

Then came the Atlantic cable. All of these instrumentalities were speedily employed for the gathering and distributing of news. And for news the American people at a very early period grew voracious. Away back in April, 1814, Nathan Hale, a nephew of the patriot spy, became editor of the *Boston Adver-*

tiser, and, in his first editorial, said one of the peculiar traits of our national character was the insatiable appetite for news: even the habitual salutation on the meeting of the people was, "What's the news?" We became, and still are, as no others on earth, a news-mad people.

As time moved on, Topliff ceased his activities, which were taken up by others. His methods were adopted in New York harbor, and later, when the Cunard Line made Halifax its first western port of call, that was the centre of interest and source of supply for European information, which was sent to Boston and the other cities of the country by pony expresses, by railway trains, and at last by telegraph.

There is a story of the cable which may interest you. The first general manager of what was called The Associated Press was one Dr. Jones. He was an authority upon telegraphs—at least he thought he was. He wrote a book on the subject. It may be found in one or two of the public libraries. In it he declared himself in no uncertain terms respecting the absurd proposal to connect America with Europe by a submarine cable. "It cannot be done," said he; "experience has shown that a relay every forty miles is necessary to carry the electric current along. And how can you have such relays in the bed of the ocean?"

"There is only one way to reach Europe by telegraphy," he continued; "that is to build a line up through British Columbia and Alaska to the Bering Sea, and thence across Siberia to Moscow, and Paris, and London." And the telegraph company adopted this view. They sent two expeditions, one to British Columbia and the other to Siberia. They were putting up poles and stringing wires, when one day a message announcing the successful operation of Mr. Cyrus Field's cable was received. In an hour their work ceased, and some rotted poles up near the Alaskan border, at a place still known as Telegraph Hill, remain as a monument of their error.

One of those who went to Siberia was Mr. George Kennan, a telegraph operator and editor of The Associated Press, who there learned of the horrors of the prison mines, and who, in book and lecture, has since done so much to enlighten the world upon the subject.

As I have said, Topliff's work was taken up by others. Among and chief of these was a Mr. Craig, who proved an ag-

gressive, enterprising, and altogether remarkable man. As an independent news-gatherer, he contested the field with the combination of New York City papers, perfected about 1850, and enjoying the aid of the newly-invented Morse telegraph lines. This combination was popularly named The New York Associated Press, although it never was incorporated and therefore never had a legal title. Its general manager was the Dr. Jones of whom I have spoken. Craig won in the struggle and displaced Jones, and for several years achieved distinction in the business.

But this New York Associated Press carried in its organization and methods the seeds of its own destruction. It was really a partnership of seven newspapers. They gathered the news of the world and sold it to the newspapers of the country published outside of the metropolis. It was inevitable that, sooner or later, there should be trouble. And so there was. Out in the West there was organized the Western Associated Press, which contracted with the New York Associated Press for an exchange of service. This went on for some years, until it grew very unsatisfactory to the Westerners. The New York organization gathered such news as it pleased, and the Western papers had no voice in the business. In 1882, on my motion, I then being a member and director of the Western Associated Press, we broke with the New York people and set out for ourselves. There was a sharp but very short-lived contest. Then there was a Compromise combination. And for ten years this lasted. Meanwhile I went out of journalism. All the while I was convinced that the method of operation of these associations was fundamentally wrong. They were all conducted as money-making ventures; that is, a limited number of newspaper proprietors organized into an association, gathered news, and sold it at a profit to other newspapers or organizations of newspaper owners. There were a dozen or more of these associations. The chief one was the New York Associated Press. As I have said, it was a partnership of seven New York newspaper proprietors. This concern gathered primarily the foreign and Washington news, as well as information respecting the happenings of New York City. It exchanged its budget of news with the smaller associations scattered over the country, exacting a differential annual payment to represent the larger value of the news provided by the NewYorkers than that of the news of the smaller

companies. There were many objections to this system. It was not always fair from a merely financial point of view. The New Yorkers held the whip-handle and naturally were led into using it to exact larger bonuses than were just. Then, too, they determined the character of the news they gathered with little care for the needs or wishes of the papers in the interior of the country, which were dependent upon them. And they had an alliance with the telegraph company which gave them reduced rates and exclusive privileges, making competition practically impossible. In such circumstances they were easily able to poison the channels of news, although I think it right to say that there is little evidence that they ever did so in any considerable degree.

Withal, it was fortunate that their ways brought disaster to their association. As I have said, the quarrel with the Western Associated Press, which operated between the Allegheny and Rocky Mountains, was patched up in 1882, and there was comparative peace for ten years. In this decade, however, new telegraph companies sprang into existence and made possible competing news associations. So in 1892 the dominance of the New York people was broken, and its work was handed over to what was then called the United Press, an institution having a small number of shareholders and practically a close corporation. Indeed, within a short time it was ruled by three men, only one of whom was a practical journalist. Out of this there was widespread discontent, but also widespread confusion. My old-time friends and former associates in the Western Associated Press were particularly disturbed. They met in general convention in Chicago, and appointed a committee to wait upon me and ask me to accept the post of general manager of the organization which they had in mind. This was the beginning in purpose as well as in fact of what seems to me to have been, in form at least, an ideal news-gathering association.

We believed that, with a self-governing people, it was all-important that they should be well-informed: informed truthfully and honestly respecting the affairs of the day. There should be no chance that they should be misled, if it were possible to achieve such an end. There was a public duty, of a very high character, involved in the matter. Not alone, if you please, that the market reports for the investor, or the merchant, or the farmer should be accurate, but—deeper and more important—

in our political life, where the very business of government was at stake and vital, the truth, impartially, without bias or alien purpose, should be furnished for the guidance of the electorate. Obviously this was not to be secured from an agency operated by a few men, owing no responsibility to any one.

Then ensued a prolonged consideration of the subject, and it was agreed, as a result, that the best thing to do was to establish a nation-wide association, of a coöperative character, with no capital, no profits, no dividends—including as members papers of every conceivable political, social, and religious bent, and subject to the control and censorship of these varied interests. This, it was believed, would give the best guaranty of unbiased, non-partisan, and wholly impartial reports of current events.

There was a four years' contest to make a success of such an institution. It was a case of private interest against public service. A large amount of money was expended by men who were wedded to the idea of a pure fountain of news service. And in the end their efforts were crowned with victory. This, my friends, is the history of the founding of The Associated Press of to-day.

And now what is it? And how does it operate? First, there are something like nine hundred members, each owning a daily newspaper and each having a vote in determining the management. These nine hundred members represent every angle of every fad or ism outside the walls of Bedlam. And not only each member, but every employee of every member—nay, more, every reader of every one of these nine hundred daily papers sits in hourly judgment on the service which The Associated Press is rendering. This criticism was expected by those of us who founded the institution, and it is not at all to be deplored. It is the thing which safeguards an honest and truthful service of news to you. There are competing organizations, and their rivalry tends to celerity in gathering and presenting the news. I do not undervalue this feature of our work, yet I regard its reputation for truthfulness and strict impartiality as the best asset of The Associated Press. It is far less important that you get prompt news than that you get true news. Every one familiar with our work knows that it is utterly impossible for any one in the service, from the general manager to the least important agent at the most remote point, to send an untruthful dispatch

and escape detection. You may write a biased or inaccurate statement for a single newspaper and "get away with it," but you cannot do it with the argus-eyed millions who read the dispatches of The Associated Press. The very magnitude of its work tends to make truthfulness and impartiality imperative. I am not laying claim to any great virtue. I am saying that, under its system of operation and in view of the millions of critics passing upon its work, it is automatically truthful and fair. As one evidence of this, it is just to say that in the twenty-three years of the present management of the news service, although we have delivered untold millions of words of news every month, we have never paid a dollar of damages in an action for libel, nor have we compromised any case.

If we made an error, we have, and always will, correct it in the most straightforward and ample fashion. We have no squeamishness about this. I am convinced that there is no tyranny greater than that of the printed word, and that a newspaper loses nothing, but gains greatly, by an honest confession of error. It is not easy to establish a reputation for infallibility; it is very easy to secure a reputation for integrity, if it is deserved. And this is the thing that is of real value.

But, after all, let us return to our "muttons." For, I dare say, you are asking, how does all this explain how the world's news is gathered and furnished you in a newspaper issued at one cent a copy? First, as to the foreign news, which is, of course, the most difficult to obtain and the most expensive. Well, in normal times there are four great agencies which, with many smaller and tributary agencies, are covering the whole world. These four agencies are the Reuter Telegram Company, Ltd., of London, which assumes responsibility for the news of the great British Empire, including the home land, every colony except Canada, and the suzerain or allied countries, as Egypt, Turkey, and even China and Japan; and the Agence Havas, of Paris, taking care of the Latin countries, France, Italy, Spain, Portugal, Belgium, Switzerland, and South America, as well as Northern Africa; and the Wolff Agency of Berlin, reporting the happenings in the Teutonic, Scandinavian, and Slav nations. These three organizations are allied with The Associated Press in an exclusive exchange arrangement. Subordinate to these

agencies is a smaller one in almost every nation, having like exchange agreements with the larger companies.

Thus it happens that there is not a place of moment in the habitable globe that is not provided for. Moreover, there is scarcely a reporter on any paper in the world who does not, in a sense, become a representative of all these four agencies. Let me explain how this comes about. Not only have we these alliances, but in every important capital of every country, and in a great many of the other larger cities abroad, we have our own men, trained by long experience in our offices in this country. This we do because, first, we are anxious to view every country with American eyes; and, second, because a number of the agencies of which I have spoken are under the influence of their governments and, therefore, not always trustworthy. We rely upon them for a certain class of news, as, for instance, accidents by flood and field, where there is no reason for any misrepresentation on their part. But where it is a question which may involve national pride or interest, or where there is a possibility of partisanship or untruthfulness, we trust our own men.

Now, assume that a fire has broken out in Benares, the sacred city of the Hindus, on the banks of the Ganges, and a hundred or a thousand people have lost their lives. Not far away, at Allahabad or at Calcutta, is a daily paper, having a correspondent at Benares, who reports the disaster fully. Some one on this paper sends the story, or so much of it as is of general rather than of local interest, to the agent of the Reuter Company at Calcutta, Bombay, or Madras; and thence it is cabled to London and Hong Kong, and Sydney and Tokyo. At each of these places there are Associated Press men, one of whom picks it up and forwards it to New York.

If the thing happens in Zanzibar, the story goes either to Cairo or Cape Town, and by the same process finds its way to London, and on to us in this country. Thus the wide world is combed for news, and in an incredibly short time is delivered and printed everywhere. When Pope Leo XIII died in Rome the fact was announced by an Associated Press telegram in the columns of a San Francisco paper in nine minutes from the instant when he breathed his last. And this message was repeated back to London, Paris, and Rome, and gave those cities the first information of the event. When Port Arthur was taken

by the Japanese in the war of 1896 it came to us in New York in fifty minutes, although it passed through twenty-seven relay offices. Few of the operators transmitting it knew what the dispatch meant. But they understood the Latin letters, and sent it on from station to station, letter by letter.

When Peary came back from his great discovery in the Arctic Sea he reached Winter Harbor, on the coast of Labrador, and from there sent me a wireless message that he had nailed the Stars and Stripes to the North Pole. This went to Sydney, on Cape Breton Island, and was forwarded thence by cable and telegraph to New York.

For its domestic service other methods are adopted. The territory covered includes the United States proper, Alaska, the Hawaiian Islands, the Philippines, the islands of the Caribbean Sea, Mexico, the Central American States, and, by an exchange arrangement with the Canadian Press, Limited, the British possessions on this continent.

The organization is, as you have been told, coöperative in its character. As a condition of membership, each one belonging agrees to furnish to his fellow-members, either directly or through the association, and to them exclusively, the news of his vicinage, as gathered by him for his own paper. This constitutes the large fountain from which our American news supply is drawn. But, as in the case of the foreign official agencies, if there be danger that an individual member is biased, or if the matter be one of high importance we use our own trained and salaried staff men to do the reporting. For this purpose, as well as for administrative work, we have a bureau in every leading city.

For the collection and interchange of this information we lease from the various telephone and telegraph companies, and operate with our own employees, something like fifty thousand miles of wires, stretching out in every direction through the country and touching every important centre. To reach smaller cities, the telephone is employed. Everywhere in every land, and every moment of every day, there is ceaseless vigil for news.

I am frequently asked what it costs thus to collect the news of the world. And I cannot answer. Our annual budget is between three and four million dollars. But this makes no account of the work done by the individual papers all over the world in reporting the matters and handing the news over to the agencies.

Neither can I estimate the number of men and women engaged in this fashion. It is easy to measure the cost of certain specific events; as, for instance, we expended twenty-eight thousand dollars to report the Martinique disaster. And the Russo-Japanese war cost us over three hundred thousand dollars.

Such, my friends, is an outline of our activities in what we call normal times. But these are not normal times. When the great European war broke on us, eighteen months ago, all of the processes of civilization seemed to go down in an hour. And we suffered in common with others. Our international relations for the exchange of news were instantly dislocated. We had been able to impress the governments abroad with the value of an impartial and unpurchasable news service, as opposed to the venal type of journalism, which was too common on the European continent. And in our behalf they had abolished their censorships. They had accorded us rules assuring us great rapidity in the transmission of our messages over their government telegraph lines. They had opened the doors of their chancelleries to our correspondents, and told them freely the news as it developed.

All these advantages ceased. The German news agency was prohibited from holding any intercourse with the English, French, or Russian organizations. Simultaneously, like commerce was interdicted in the other countries. The virtues of impartial news-gathering at once ceased to be quoted at par. Everywhere, in all of the warring lands, the Biblical rule that " He that is not with me is against me " became the controlling view. Government telegrams were obviously very important, and there was no time to consider anywhere any of the promised speed in sending our dispatches. Finally, censorships were imposed. This was quite proper in principle. Censorships are always necessary in time of war. But it is desirable, from every point of view, that they be intelligent.

I am sorry to say that, for crass stupidity, some of the European censoring has never been equalled unless it was in the days of our Civil War. In 1862, Secretary Stanton instituted at Washington a military control of news telegrams which will ever remain a monument of imbecile autocracy. Those in charge of the business were wholly without qualifications for the work, and their antics were both annoying and ludicrous. For instance, information printed in the Washington papers without objection

could not be sent to Boston or Chicago, but was frequently copied by the Boston and Chicago papers after the Washington papers had been smuggled through the Confederate lines to Richmond, the news printed in the Richmond papers, and these, in turn, smuggled back through the Federal lines to the North.

Well, like doltish management has characterized much of the censorship abroad and has increased our difficulties. Mark you, we fully recognize the propriety and need of a military censorship and have no thought of objecting to it. But when the business is put in the hands of people who, alike because of their censurable habits or their lack of ordinary elementary education, are often in no condition to exercise any discriminating judgment, we do protest.

Nevertheless, I feel that we have fared pretty well in the business of reporting this war. We have made distinct progress in teaching the belligerents that we hold no brief for any one of them, and, while each would much rather have us plead his cause, they are coming to see why we cannot and ought not to do so. And our men, I am glad to say, are everywhere respected and accorded as large privileges as, perhaps, in the light of the tension of the hour, could be reasonably asked.

During this war we have more men and more offices in Europe than any other news-gathering organization ever had, and are expending even greater sums. Last week, for example, we received the speech in the Reichstag of Chancellor von Bethmann-Hollweg and the German Baralong Note not only by wireless but also by the costly cable route through Holland and England to New York. In tolls alone the cost to The Associated Press of such matter was over one dollar a word—yet this all goes to you in your penny paper.

When the Austro-Hungary Government prepared a reply to the American note on the sinking of the *Ancona* the reply was relayed by Associated Press men from Vienna to Berlin, from Berlin to The Hague, from The Hague to London, and from London to New York, and delivered, in spite of the censorships, to virtually every newspaper reader in the United States thirty-six hours before it was decoded in the State Department at Washington.

Yesterday's *London Times* complained that the version of Germany's Baralong correspondence published in London was in-

complete, although neutral countries received the full German report, and added:

"Some idea of the importance attached by the German Government to the correspondence may be gleaned from the fact that the whole dispatch was sent direct from Berlin by wireless to New York, where it was transmitted exact to 1000 leading American newspapers through The Associated Press."

There is much misunderstanding in the public mind respecting the limitations which we believe, with distinct propriety, have been imposed upon The Associated Press.

Also, many people are unable to distinguish between Associated Press despatches and special telegrams for which we have no responsibility, and yet for which we frequently receive undeserved blame.

There are certain things which it should do, and others which it must not do. It should report the important events of the day as fairly and truthfully and impartially as is possible for human beings to do. It may not go further. It must give both sides of a question fair treatment. But it must not hint that either side is right or wrong. It may be claimed that this sort of negative work has no value; that The Associated Press sees a great wrong and makes no sign of disapproval. It sees a movement for the betterment of mankind which is of the highest moment, and does not lend a hand to help the thing along. Let us see. There is an underlying belief that the American people are capable of self-government. If so, they must needs be able to form a judgment. And we conceive it to be of very great importance that the people be given the facts free from the slightest bias, leaving to them the business of forming their own judgment. Let us see what any other method of dealing with the news of the day must mean. If a news agency is to present somebody's view of the right or wrong of the world's happenings, whose view is it to be? And what assurance are we to have that the somebody's view is the right view? And if it is the wrong view, what then?

One final word: The Associated Press, reaching as it does with its dispatches the great body of the American people, has very large responsibility. And we believe the business of news-gathering, when properly done, has a distinct moral value. Notwithstanding all I have said about the impartiality of the association, and nowithstanding the fact that it takes no part for

either side in any controversy, it nevertheless has an enormous influence upon American life. Adopting the terminology of our medical friends, "We cure diseases upon the body-politic by the aseptic and not by the antiseptic method."

Given a correct environment, we leave nature to do the rest. If, with the truth before them, the people choose to go wrong, that is their affair, not ours. We furnish an atmosphere of truth which necessarily leads to purifying the cesspool. We furnish the light which flames out into the dark places and makes impossible "treason, stratagem, and spoils."

We do not hunt out scandals or gruesome tales for the sole purpose of pandering to vitiated desires, but bend our energies toward writing the real and abiding history of the day. The association is a voluntary union of a number of gentlemen for the employment of a certain staff of news reporters to serve them jointly. For its work it derives no advantage from the government, from any state or municipality, from any corporation, or from any person. I have no thought of saying that it is perfect. The frailties of human nature attach to it. But of this I am certain: If, in its form of organization or its method of operation, it is in violation of any law, divine or human, it is the very last institution in this country to seek to avoid its responsibility. If any one can devise or suggest a better way to do the work it is seeking to do, it will be glad to adopt it, or to permit some one else to put it in operation. The thing it is striving for is a truthful, unbiased report of the world's happenings, under forms that are legal, and not only conformable to statutes, but ethical in the highest degree.

The Action on Boiling Acetic, Propionic, and Butyric Acids on Aluminum. R. SELIGMAN and P. WILLIAMS. (*Journal of the Society of Chemical Industry*, vol. xxxv, No. 2, January 31, 1916.)—The work described in this paper forms part of an extended inquiry which has been undertaken with the object of clearing up some of the anomalies to be found in literature dealing with the action of acids upon aluminum. The present contribution relates only to one small section of the work; namely, the action of certain hot concentrated, volatile fatty acids.

Aluminum stills have been used for a number of years for the distillation of acetic acid, and it has been found that, whereas some parts of the apparatus withstand the action of the acid in a very

satisfactory manner, other parts are subject to rapid corrosion. It was considered, at the outset of the experiments made to determine the conditions governing the rate of attack, that the presence or absence of air might be the main factor, but this assumption was found to be erroneous, although there was some evidence that, in the absence of oxygen, dissolution is more uniform than when oxygen is present. On the other hand, the question of concentration was found to be all-important, quite exceptionally narrow limits defining the strength of acid which causes rapid dissolution of the metal. As was to be expected, the rate of dissolution falls as the strength of the acid increases, so that a 99 per cent. acid has only about one-tenth the action upon aluminum of a 90 per cent. acid. But the astonishing fact was brought to light that the removal of the last 0.05 per cent. of water is sufficient to raise the rate of dissolution a hundred-fold, while, conversely, the addition of 0.05 per cent. of water to a corrosive acid suffices to stop the action.

Experiments on butyric acid showed that its action on aluminum was similar in all respects to that of dehydrated acetic acid, rapid dissolution of the metal taking place. This experience led to a similar series of experiments with propionic acid. In this case also perfect analogy between the acids was established. It has not been possible to experiment with dehydrated formic acid, but the action of boiling 77 per cent. acid has been briefly examined. This acid attacks aluminum very rapidly, a crystalline salt being formed. Finally experiments were made with a mixture of higher fatty acids, containing 55 per cent. palmitic acid, 40 per cent. stearic acid, and 5 per cent. oleic acid. At temperatures up to 300° C., aluminum has been presumed to be quite unaffected by these acids, but occasionally, in the course of industrial work, a case of pitting has come to light which it is quite impossible to explain.

"Safety-first" Exhibit, Washington, D. C., February 21-26, 1916.—There was held in Washington, during the week of February 21–26 inclusive, a "safety-first" exhibit in which all of the government departments took an active part. This exhibit took on a national aspect, as manufacturers and operators from all over the country were invited to be present, in order that they might see what the Government of the United States had done in "safety-first" work.

Secretary of the Interior Lane had sent a letter to the governor of each state inviting him to send a delegate, and asking that the Chief Mine Inspector, a representative of the Industrial Commission, or of other agencies engaged in compiling statistics relating to the various mineral industries, also attend this exhibition.

INVESTIGATION OF MAGNETIC LAWS FOR STEEL AND OTHER MATERIALS.*

BY

JOHN D. BALL, E.E.,

Consulting Engineering Department, General Electric Company.

In coming before you this evening I appreciate the fact that I have the honor of addressing an old and established scientific society, and I have taken an old and established scientific subject, "Magnetism."

Magnetism, while quite different from electricity, is so closely associated with the latter in electric machines and in science in general that we now consider magnetics as a branch of electrical engineering, and as such its study is probably the oldest of the component parts which made the present science. It is therefore gratifying that upon this occasion I find present representatives of the American Institute of Electrical Engineers.

From the length of time magnetic phenomena have been observed, we might think that the subject is so old, and the work done by distinguished experts so thorough, that there is little left to be accomplished. As a matter of fact, much has been done and learned since the peculiar properties of the lodestone were first observed, yet to-day the subject is by no means thoroughly understood. Our formulæ are mostly empirical, and the variations in magnetic material under different, and even under apparently the same, conditions show so many unaccountable variations from what we consider as correct, that a book on "What we Cannot Account for in Magnetic Behavior" would be easy to write.

That the subject is a live one is witnessed by the number of articles which have been presented before this and other learned societies.

I will not attempt to give you a *résumé* or bibliography of magnetic research in general, but will present to you results of some of our own investigations made during the past two years.

The work has been done with two purposes in view:

Primarily to study magnetic phenomena with a hope of aiding

* Presented at a joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, December 2, 1915.

the discovery of their true nature, and secondarily to study the magnetic properties of materials to assist in the economical design of apparatus.

Probably the two most valuable magnetic laws which we have to-day are the reluctivity equation of Dr. Kennelly, which is a modified form of Fröhlich's equation, and the 1.6 law of Dr. Steinmetz. These two laws give us our best method of attack on magnetic problems. A considerable number of test results has been obtained and much literature written attempting to show apparent inconsistencies in these laws, especially referring to the latter. The fundamental idea of the present investigation was, therefore, to determine the accuracy and cause of these apparent deviations of observed test values from the reluctivity equation of Kennelly and the hysteresis equation of Steinmetz. About three years ago Dr. Steinmetz suggested that these apparent deviations might be due to the fact that the materials tested were not homogeneous. As it was found that the deviations were most noticeable in silicon steel, and as the hysteresis losses in this material are especially interesting from the standpoint of electrical manufacturers, properties of this steel were closely examined. On the theory that heterogeneous materials cause the deviations from magnetic laws, it became necessary to separately determine the properties of steel, free from scale, and the properties of the scale itself. It became also desirable to further investigate the theory by artificially reproducing the characteristics of a heterogeneous material by testing a sample which consisted of two component metals; one of the samples selected was a ring which was practically pure iron, and the other cobalt. The two rings were fastened together and tested as a single sample, after which the properties of each ring were determined separately.

During the process of the investigation we also studied the second hysteresis law of Dr. Steinmetz, or the hysteresis losses in unsymmetrical loops; that is, where the mean introduction of the loop occurs at a density other than zero.

The present paper is divided into the following divisions:

I. Review of the reluctivity law of Kennelly.
II. The hysteresis law of Steinmetz.
III. The theory of the changes in flux distribution in heterogeneous material to account for apparent deviations in the above laws.

IV. Properties of scale from silicon steel.
V. Application of scale data to show distribution of flux and losses in sheet steel as affected by the presence of steel.
VI. Tests of iron and cobalt separately and together to reproduce effects of steel with scale.
VII. Applications of data in calculating losses.
VIII. Brief *résumé* of investigation to determine losses in unsymmetrical loops.
IX. Appendix: Properties of scale from silicon steel of general interest and value, but not pertinent to the present investigation.

I. The Reluctivity Law of Kennelly.

The reluctivity law of Dr. Kennelly as announced is: that for magnetic materials the reluctivity (which is the reciprocal of the permeability), when plotted against the magnetizing force H, gives a curve which, from minimum reluctivity upwards, approximates a straight line over a wide range of values.[1] However, as pointed out by Dr. Kennelly, we find in most cases that the curve is not a straight line, but rather two straight lines joined by a sharp, decided bend. From plotting and examining several hundred curves for many varieties of steel, for nickel, monel metal, "binel" metal, and other metals, we have found that for a given material the bend apparently occurs at a definite value of magnetizing force H, irrespective of the flux density B. Closer examination indicated that above this value of H there are no bends, but below this value there are often evidences of several bends. In any curve there is but one salient deflection, the others being much less pronounced. A variety of these curves are shown in Dr. Kennelly's article.

A curve of the test results of a sample of high silicon steel is shown on Fig. 1, which may be taken as a typical curve. Other curves for silicon steel may be found in another paper.[2]

The reluctivity, ρ, is given by the equation $\rho = a + \sigma H$, wherein:

[1] "Magnetic Reluctance," A. E. Kennelly, *Trans. A. I. E. E.*, vol. viii, 1891, pp. 485–517.

[2] "Reluctivity of Silicon Steel," J. D. Ball, *Gen. Elec. Review*, vol. xvi, 1913, pp. 750–754.

α is a constant representing the distance from the X axis to the intercept of $\rho - H$ curve if continued along the straight line.

σ is a constant representing the slope of the line. We may consider that α represents the magnetic hardness of the material, as the harder the metal (magnetically) the greater the value of α. The constant σ has been named the coefficient of magnetic saturation because its reciprocal gives the value of absolute saturation of metallic induction.[3] Tests made at very high magnetizations by use of the isthmus method,[4] check ultimate saturation values as found by $\frac{1}{\rho}$ of the $\rho - H$ curve taken at moderate field strengths.

As $\rho = \frac{H}{B}$ and also $\rho = \alpha + \sigma H$, then the induction,

$$B = \frac{H}{\alpha + \sigma H}.^{5}$$

Examining the curve Fig. 1, we note that from maximum permeability to about $H = 80$ the flux apparently enters a material having an apparent ultimate saturation of $B = 17{,}000$; then later the curve shows a changed condition, as if the flux passed through material whose apparent ultimate saturation is in the neighborhood of $B = 20{,}000$, and whose α shows a harder material. This indicates that the two lines apparently may represent two magnetic materials, one of which takes most of the flux first, and the other carries the additional flux after the first is presumably saturated, or the permeability of the second part begins to increase much more rapidly than in the first.

Before going into detail further concerning the theory of

[3] "On the Law of Hysteresis," C. P. Steinmetz, *Trans. A. I. E. E.*, vol. ix, 1892, p. 625 *et seq.*

[4] See "Electrical Properties of Iron and Its Alloys in Intense Fields," Sir Robert Hadfield and Professor B. Hopkinson, *Journ. I. E. E.*, vol. lvi, 1911. pp. 235–306, etc.

[5] There are reasons why the true metallic density $4\pi I$, which is $B - H$, should be used for extrapolation and other applications of this law; this has also been written B_o. In this case the metallic reluctivity $\frac{H}{4\pi I}$ would be represented by $\rho_o = \alpha_o + \sigma_o H$ and

$$B = \frac{H}{\alpha_o + \sigma_o H} + H$$

This is discussed in a previous paper, "Some Notes on Magnetization Curves," *Gen. Elec. Rev.*, vol. xviii, 1915, pp. 331–35. For the ranges involved in the present discussion, B_o is so nearly identical with B that the difference is negligible and is not taken into account.

changes in flux paths it is desirable to briefly review the hysteresis law of Steinmetz.

II. The Hysteresis Law of Steinmetz.

In the early part of 1892, Dr. Steinmetz presented the well-known classic paper on "The Law of Hysteresis" and gave us the law $h = \eta B^{1.6}$[6] wherein:

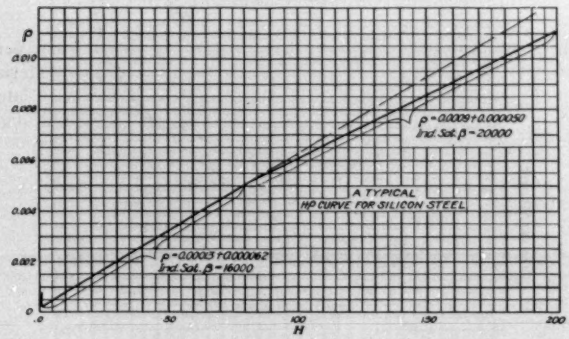
h = the hysteresis loss per cycle in ergs per cm.^{3}

B = the maximum induction.

η = a numerical coefficient depending upon the material.

The great value of the discovery has been recognized and re-

FIG. 1.



quires no comment here. Along in 1910–11, shortly after the German specifications were adopted that the standard test of steel should be made at $B = 15.000$ as well as $B = 10,000$,[7] a number of experimenters made calculations which gave for the higher ranges of inductions values of the exponent on the order of 3. Some of these values have been published. The calculations were in error, due to certain misconception of taking the percentual slope of the curve $\log h - \log B$ as the exponent where the curve was not a

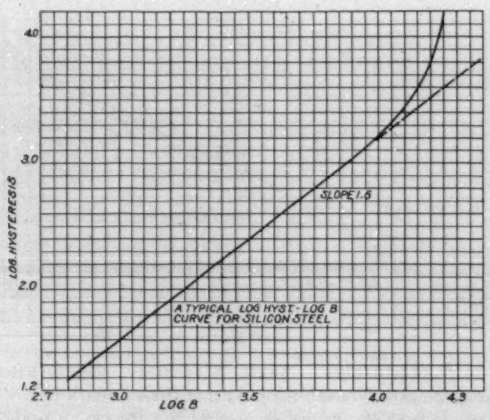
[6] "On the Law of Hysteresis," C. P. Steinmetz, *Trans. A. I. E. E.*, vol. ix, 1892, pp. 3–51; also vol. ix, 1892, pp. 621–729; vol. xi, 1894, pp. 570–608.

[7] For present standard see V. D. E. Rule's "Normalien für die prüfung von Eisenblech."

straight line or the original $h - B$ curve was not exactly parabolic. Examination of data, however, does show an apparent increase of the exponent at the higher inductions, the exponent increasing to, say, 1.63 at $B = 15{,}000$

Tests on many samples of 2½ per cent. silicon steel and 3½ per cent. silicon steel as commercially used show losses at $B = 15{,}000$ to be apparently 30 per cent. higher than would be given by the loss at $B = 10{,}000$ and strict application of the law. In other words, the ratio of losses at $B = 15{,}000$ and $B = 10{,}000$ is about 2.5 to 3.5 instead of the value of $\left(\frac{15{,}000}{10{,}000}\right)^{1.6} = 1.91$.

FIG. 2.

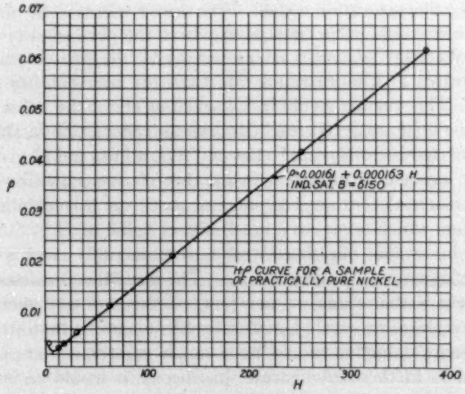


Plotting a typical $\log h - \log B$, we find results as given on Fig. 2. The solid curve represents the observed data, and the dotted continuation of the straight line shows what results might be expected if the law was absolutely correct. If we assume that the 1.6 law holds, we see that to about $B = 10{,}000$ the flux enters a material of certain characteristics, but beyond that point the more appreciable amount of the flux is going through some magnetically harder material characterized by greater reluctivity and a higher value of η.

III. The Theory of Changes in Flux Distribution to Account for Apparent Deviations in Magnetic Laws.

As pointed out, the bend of the reluctivity curve indicates a non-homogeneous material or a material whose component parts may be divided into two magnetic materials, whose characteristics are different, and in consequence carry different percentages of flux as the magnetizing forces are varied. In such a case the softer material would carry a correspondingly greater amount of flux until approaching saturation reduces the permeability, after which the additional flux is forced into the harder material, whose

FIG. 3.



permeability is then correspondingly higher than before. The percentage of flux in the harder material will then increase very rapidly, due to the fact that the softer material, is becoming saturated, and can carry little additional flux. At varying values of magnetizing force the percentage of flux in the two materials constantly varies, due to the fact that the rate of change of their respective permeabilities is constantly varying.

It would be expected that if pure or homogeneous materials were taken the reluctivity curves would be straight. Tests have been obtained showing this to be true, as, for example, Fig. 3 gives an $H - \rho$ curve for a sample of nearly pure nickel. The chemi-

cal analysis showed: Ni 98.91, Cu 0.33, Fe 0.31, Mn 0.21, Si 0.07, Co 0.15. Here we see no evidences of bend, but a straight line from approximately $H = 9$ ($B = 3000$) to $H = 377$ ($B = 6350$), the limit of the test. A study of this curve would indicate that in this case the flux is passing through a material whose magnetic characteristics are constant throughout the range of the test.

Referring to the hysteresis law, the deviation from the straight line in the $\log h - \log B$ curve also indicates a heterogeneous material. The most prominent deviations from the reluctivity and hysteresis laws do not occur at the same value of the magnetizing forces, nor would it be expected. The bend of the reluctivity curve would be predicted at a value of H where one material approaches the saturation value. The rapid increase of the hysteresis loss would occur at a point where the permeability of the harder material (which is characterized by the greater value of η) increases at a more rapid rate than the permeability of the softer. This change would be expected at about the value of H, where the softer material reaches maximum permeability, although not necessarily at this point. Beyond this, additional H gives less relative increase of induction, while the relative induction in the second material continues to increase until its permeability is a maximum, which occurs at a much higher value of H.

We know that our sheet steel as commercially used is by no means magnetically homogeneous. The fact that it is especially prominent is that about 10 per cent. of the ordinary sheet consists of scale, which scale is naturally less magnetic than iron and at the same induction would have much greater hysteresis loss. In order to further demonstrate this theory, it would be interesting to have a purely theoretical case, where a heterogeneous material forms two or more magnetic paths in multiple, and note the behavior of the combined curves when calculated by assuming the component part thereof to be subjected to the same values of excitation. Unfortunately this is not practical, as it would be necessary to have values of the normal induction curve below maximum permeability for at least one of the components, and we have not as yet been successful in obtaining an equation of the magnetization curve below maximum permeability. A curve representing materials might be drawn at random, but results derived therefrom would necessarily be neither accurate nor convincing. We

are therefore forced to investigate our theory with actual data, which, after all, is the correct method of investigating empirical formulæ.

As steel and scale are the salient components of our sheet steel, it becomes desirable to determine the characteristics of scale from silicon steel when removed from the steel itself. We will therefore leave the general investigation of magnetic laws for the time being, to give results of tests on steel scale.

IV. Properties of Scale from Silicon Steel.

It is a well-known fact that when steel is heated the exposed surfaces combine chemically with surrounding gases and form a thin scale. Such formations appear when steel is taken from rolling mills, and the thickness thereof is usually greater after materials are subjected to annealing processes. In thin sheets the scale on both sides is usually sufficient to amount to about 10 per cent. of the total cross-section. In silicon steels this scale is usually in flakes, and sometimes may be easily removed from the sheets. Often large sections may be peeled off, in which manner samples were obtained for this investigation. The samples tested were built of large flakes accumulated from time to time, and therefore are more representative than if a whole sample was taken from one heat or lot only.

The study of steel scales and a knowledge of their properties were required primarily for assistance in determining magnetic laws for materials wherein scale exists, thus rendering test specimens non-homogeneous. Also, it is of interest to be able to determine effect of scale in electrical machines wherein the scale occupies a portion of a section of a magnetic core.

Tests were made on a scale from steel containing 3.5 to 4.3 per cent. silicon. One sample of scale was obtained from steel annealed in the ordinary way, which is herein referred to as "mill-annealed." The second variety was obtained from steel annealed at high temperature in a vacuum furnace, which will be herein designated as "vacuum-annealed scale."

For the present discussion the mill-annealed scale is used, but, as the properties of scale from vacuum-annealed steel are of general value, results of these tests are given in the Appendix.

SCALE FROM MILL-ANNEALED STEEL.

Physical Appearance and Size of Sample.

The scale from mill-annealed silicon steel is dark gray in color, is somewhat pitted, and is fairly rough. The material is reasonably tough, but is, of course, much more brittle than the steel itself. The sample tested was made up of ring punchings 8.89 cm. (3.5 inches) outer diameter, 6.86 cm. (2.9 inches) inner diameter, and weighed 85 grammes (0.187 pound). The average thickness of the sheets was 0.0064 cm. (0.0025 inch). The scale was obtained from sheets 0.035 cm. (0.014 inch) thick.

Chemical Analysis.

The first analysis of this material gave the following results:

Si	7.02
S	0.047
Mn	0.08
C	0.054

Analysis for oxygen gave 1.2 per cent., which was rather surprising, as scale is usually considered as a magnetic oxide, which would, of course, have a larger percentage of oxygen.

A later, and probably more reliable, analysis gave:

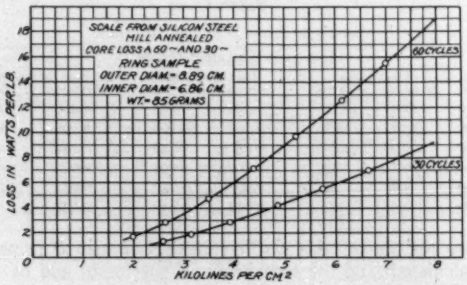
Si	5.28	5.52
S	0.047	0.046
P	0.042	0.041
Mn	0.310	0.300
C	0.307	0.300
Total Fe	75.84	76.21
Total per cent.	81.826	82.417

As before stated, the analysis for oxygen gave only 1.2 per cent., but it is well known that such determinations are often not reliable. In all probability, the 18 per cent. missing in the above tabulations is oxygen. We know that all of the silicon and some of the iron exist as oxides. Considering the silicon to appear as SiO_2, and assuming the iron in the oxide form to be in Fe_3O_4, calculated values may be derived from the analysis of the first specimen tabulated above, giving the following possible chemical content:

SiO_2	11.23
S	0.047
P	0.042
Mn	0.310
C	0.307
Fe (free)	43.764
Fe_3O_4	44.3
Total	100.00

The above table of possible values is undoubtedly not entirely correct, as some of the silicon may be in the metallic form, and the iron doubtless appears not only as metallic iron and Fe_3O_4, but there may also be other iron oxides present, making the chemical contents of a more complicated nature.

FIG. 4.



Resistivity.

A sample of mill-annealed scale 0.0050 cm. (0.002 inch) thick was secured for resistivity measurements. The average of the measurements gave a resistivity of 126.6 microhms per $cm.^3$ at 25° C. The individual values varied from 107 to 157. A test on 0.0064 cm. (0.0025 inch) scale gave 140 microhms per $cm.^3$, which lies within the results obtained on the thicker scale. Resistivity of silicon sheet steel, such as produced this scale, is usually between 55 and 60 microhms. Ordinary sheet steel gives about 12, and cast iron 80 to 85 microhms.

Specific Gravity.

The specific gravity determination of this scale gave 5.54. The gravity of the steel itself is approximately 7.5.

Core Loss.

Core loss tests were made on the ring samples, at 60 cycles and 30 cycles, at inductions of from $B = 2000$ to $B = 7500$. The results of tests are shown on curve, Fig. 4. Data derived from the curves are tabulated with the discussion of the hysteresis loss.

Hysteresis Loss.

The hysteresis loss at various densities was first determined from the core loss tests by using the separation method. This was done by taking values from the core loss curves at 60 cycles and 30 cycles and obtaining the loss per cycle, as shown in Table I.

TABLE I.

Losses in Scale from Silicon Steel

(Losses in watts per pound.)

B	Total losses		Loss per cycle		Loss per cycle at 60 cycles	
	60 cycles	30 cycles	60 cycles	30 cycles	Hysteresis	Eddy
7500	17.4	8.5	0.29	0.283	0.276	0.014
6000	12.2	5.95	0.203	0.198	0.193	0.010
5000	9.0	4.4	0.15	0.147	0.144	0.006
4000	6.1	2.95	0.102	0.095	0.094	0.008
3000	3.6	1.70	0.06	0.057	0.054	0.006
2500	2.5	1.2	0.042	0.040	0.038	0.004

From the above table the hysteresis losses in ergs per cm.^{3} were calculated, and the logarithms of the losses and of the inductions taken, as shown in Table II.

TABLE II.

Hysteresis Losses in Scale from Silicon Steel.

B	Hysteresis ergs per cm.^{3}	Log B	Log hyst	η ($x = 1.6$ assumed)
7500	33,700	3.875	4.528	0.0222
6000	23,570	3.778	4.373	0.0212
5000	17,580	3.699	4.245	0.0212
4000	11,475	3.602	4.060	0.0198
3000	6,595	3.477	3.819	0.0180
2000	4,640	3.398	3.667	0.0170
Average				0.0199

FIG. 5.

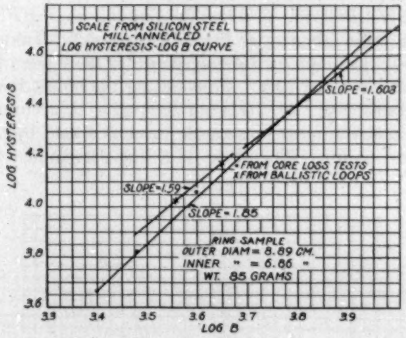
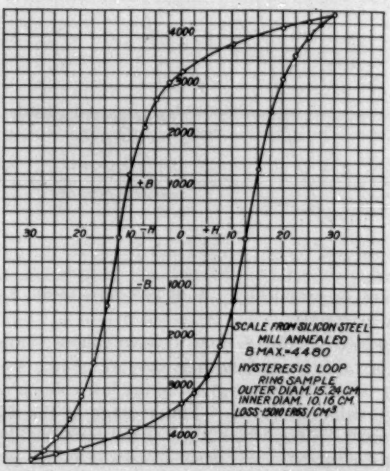

SCALE FROM SILICON STEEL
MILL-ANNEALED
LOG HYSTERESIS-LOG B CURVE
SLOPE = 1.603
FROM CORE LOSS TESTS
FROM BALLISTIC LOOPS
SLOPE = 1.59
SLOPE = 1.85
RING SAMPLE
OUTER DIAM = 8.89 CM.
INNER " = 6.86 "
WT. 85 GRAMS
LOG HYSTERESIS
LOG B
4.6
4.4
4.2
4.0
3.8
3.6
3.3
3.4
3.5
3.6
3.7
3.8
3.9

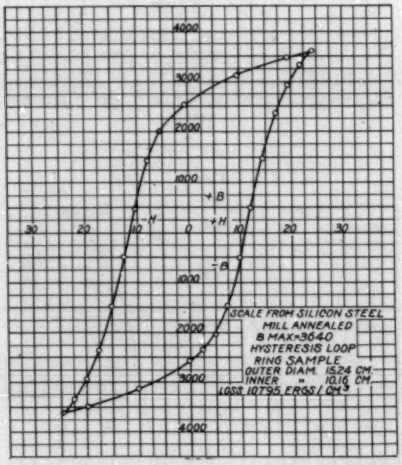
FIG. 6.


4000
3000
2000
+B 1000
30
20
10
-H
0
+H
10
20
30
-B 1000
2000
3000
4000
SCALE FROM SILICON STEEL
MILL ANNEALED
B MAX. = 4480
HYSTERESIS LOOP
RING SAMPLE
OUTER DIAM. 15.24 CM.
INNER DIAM. 10.16 CM.
LOSS 1500 ERGS / CM.3

A plot of the log hysteresis – log B is shown on Fig. 5.

In order to find the value of the constants in the Steinmetz equation, $h = \eta B^{1.6}$, the slope of the line log h – log B was next determined and evaluated by the $\Sigma\Delta$ method.[8] Taking all the above points, the slope of the line, which is the value of x in the equation, proves to be 1.83. Considering the points lying on the line, we obtain 1.85. As 1.6 is not claimed to be accurate at very low inductions, the most reasonable value is found by taking the three highest points. The slope of a line determined from this

FIG. 7.



point is 1.603, or practically 1.6, as has been found for a variety of magnetic materials.

In order to evaluate η and to have values comparable with constants for other materials, it is best to assume $x = 1.6$. The values of η so obtained are given in the last column of Table II. The average value is 0.0199. The average of the three highest points is 0.0216. From the nature of the tests the above results, especially at low values, are likely to be somewhat in error.

[8] "Engineering Mathematics," Steinmetz.

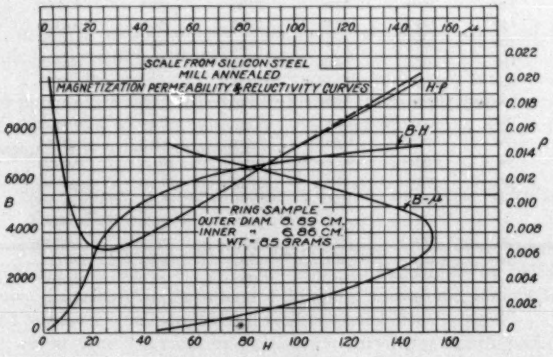
Hysteresis losses were also taken by the usual ballistic galvanometer method. Loops were obtained at $B = 4487$ and $B = 3639$, and are shown on Fig. 6 and Fig. 7 respectively. The integration of the loops gives values shown in Table III, wherein the logarithms of the values are included.

TABLE III.

Hysteresis Losses in Scale. Ballistic Tests.

B	Hysteresis ergs per cm.³	Log B	Log hysteresis	η ($x = 1.6$ assumed)
4480	15,010	3.651	4.176	0.0216
3640	10,795	3.561	4.033	0.0216

FIG. 8.



Obtaining the slope of the log h – log B line, we have 1.59. These points are shown, together with hysteresis points obtained from the core loss curve, on Fig. 5. Assuming $x = 1.6$ for the ballistic values, we find $\eta = 0.0216$, which agrees with the three upper points before mentioned. We may therefore, with reasonable accuracy, express the hysteresis loss of this sample as $h = 0.0216\, B^{1.6}$.

Magnetization, Permeability and Reluctivity.

Two tests for magnetization curves were made and found to be within good agreement. The method of test was the common

one of reversing various currents in a magnetizing winding and noting flux change by means of a ballistic galvanometer. Results of these tests are given in Table IV, and the average of the two tests is plotted on Fig. 8. On this sheet are plotted the $B-H$, $B-\mu$, and reluctivity $H-\rho$ curves. The reluctivity gives practically a straight line from $H=40$, which condition, as before stated, has been found for various metals.

TABLE IV.

Magnetization Data of Scale from Silicon Steel.

	B				
H	Test 1	Test 2	Average	$\mu = B/H$	$\rho = H/B$
150	7425	7555	7490	50.0	0.0202
140	7306	7566	7388	52.6	0.0190
130	7187	7332	7260	56.0	0.0179
120	7083	7190	7136	59.4	0.0168
110	6964	7054	7009	63.6	0.0158
100	6890	6920	6905	69.1	0.0145
90	6696	6781	6739	74.9	0.0134
80	6514	6600	6557	82.0	0.0122
70	6290	6380	6335	90.5	0.0110
60	6064	6121	6093	101.5	0.0099
50	5740	5770	5755	115.0	0.00868
40	5266	5283	5275	132.0	0.00766
30	4527	4497	4512	150.5	0.00665
20	2960	2991	2975	148.8	0.00675
10	918	879	899	89.9	0.0111
5	287.7	278	283	55.6	0.0177
3	149.0	144.7	147	49.0	0.0204
2	94.9	81.0	93	46.5	0.0215

Examination of Fig. 8 shows the reluctivity curve to be a straight line from $H=40$ to $H=105$, at which latter value the line bends slightly. From $H=105$ to the end the points also lie on a straight line. Taking the equation of this line as $\rho = a + \sigma H$, evaluating the constants by the $\Sigma\Delta$ method, gives

From $H=40$ to $H=105$:—

$$\rho = 0.00289 + 0.000117\ H$$

$$\text{Saturation } B = \frac{1}{\sigma} = 8550$$

From $H=105$ on:

$$\rho = 0.0033 + 0.000112\ H$$

$$\text{Saturation} = 8900$$

From these equations we may find the equations of the magnetization curves to be

From $H = 40$ to $H = 105$

$$B = \frac{H}{0.02289 + 0.000117\,H}$$

From $H = 105$ on:

$$B = \frac{H}{0.0033 + 0.000112\,H}$$

The maximum permeability of the material is about 154 at an induction $B = 3700$.

The results of these tests show two especially interesting features:

1. The loss in the scale itself apparently follows the Steinmetz law.

2. From maximum permeability the reluctivity curve of the scale is practically a straight line.

The slight bend in the reluctivity curve at $H = 105$ is accounted for in the same manner as for sheet steel. The scale itself consists of a mixture of iron, silicon, oxides, and impurities, and is not magnetically alike throughout.

V. Distribution of Flux and Losses in Steel and Scale Calculated from Test Results on Scale Alone.

Having now seen that the scale from steel follows the magnetic laws under discussion, we now desire to determine, by calculations, the nature of its influence on the measured magnetic values and losses of steel upon which scale appears.

If we take a typical magnetization curve representing silicon steel as entirely free from scale and entirely magnetically homogeneous throughout we may expect the following characteristics:

Saturation: $B = 20{,}000$.

Maximum Permeability: $\mu = 5000$, occurring at $B = 5000$. Then at maximum permeability $H = \frac{5000}{5000} = 1$. In the equation of the magnetization curve, $B = \frac{H}{\alpha + \sigma H}$, σ would then be $\frac{1}{20{,}000}$, or 0.00005.

At $H = 1$, $\rho = \frac{1}{5{,}000} = 0.0002$.

Also $\rho = \alpha + 0.00005\,H$.

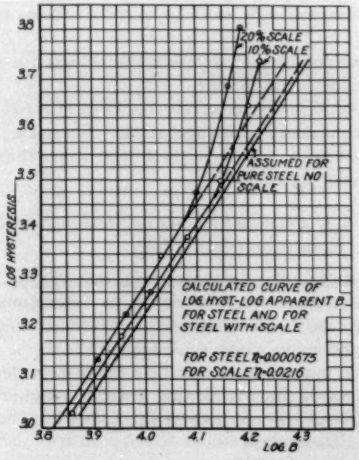
From above, $a = 0.0002 - 0.00005 = 0.00015$.

For the typical magnetization curve beyond maximum permeability we then have:

$$B = \frac{H}{0.00015 + 0.00005\,H}$$

From this equation we obtain values of B corresponding to various values of H as shown in Table V, in which table the values of B corresponding to the same values of H are given for scale

FIG. 9.



from silicon steel, which values are taken from Fig. 8 and accompanying data in Table IV.

Assuming a total cross-section area of steel and scale as 1 cm.², of which 90 per cent. is steel and 10 per cent. is scale, the flux in the steel and scale are given in Table V, columns 4 and 5 respectively. The total flux, or apparent B, of the mixture is given in column 6.

TABLE V.

Values of Flux in Steel and in Scale for 20 per cent. Scale.

	B		Flux in 0.9 cm.² of steel	Flux in 0.1 cm.² of scale	Total flux or apparent B of mixture
H	In steel	In scale			
2	8,000	93	7,200	9	7,210
3	10,000	147	9,000	15	9,015
4	11,420	200	10,300	20	10,320
6	13,330	400	12,100	40	12,140
10	15,400	900	13,880	90	13,970
20	17,400	2,975	15,680	298	15,980
30	18,200	4,512	16,400	451	16,850

We have previously found that in the Steinmetz equation for hysteresis an average of certain tests gives a value of $\eta = 0.000675$ for silicon steel. The present investigation shows that for scale η may be taken as 0.0216. Assuming the hysteresis law to hold throughout the range for steel free from impurities, we obtain for the densities of Table V hysteresis losses as given in Table VI. In this table are also given the losses for 0.9cm.³ of steel and 0.1 cm.³ of scale, which, added together, give the total hysteresis losses per cm.³ of the mixture. The logarithms of the hysteresis losses and logarithms of apparent densities are also tabulated. Plotting the log hysteresis and log B, we find on Fig. 9 that the curve is a straight line to about $B = 12{,}000$, beyond which the increase in hysteresis is greater than if the 1.6 law held for the mixture. This agrees with observations made by several authors, and might easily account for the apparent increase of hysteresis in sheet steel at high inductions, concerning which much has been

TABLE VI.

Hysteresis Loss for Steel, Scale and Mixture with 10 per cent. Scale.

H	Hyst. in steel per cm.³	Hyst. in steel 0.9 cm.³	Hyst. in scale per cm.³	Hyst. in scale 0.1 cm.³	Total hyst. in 1 cm.³ of mixture	Log hyst.	Log of apparent B
2	1183	1065	29.4	3	1068	3.029	3.858
3	1695	1525	62.0	6	1532	3.185	3.955
4	2090	1880	104	10	1890	3.277	4.013
6	2690	2420	318	32	2452	3.389	4.084
10	3390	3050	1130	113	3163	3.500	4.146
20	4130	3700	7800	780	4480	3.651	4.204
30	4420	3980	14.950	1495	5475	3.738	4.226

For steel $\eta = 0.000675$
For scale $\eta = 0.0216$

written. For the straight part of the curve the slope is 1.59, or approximately 1.6. Assuming the hysteresis exponent to be 1.6, the higher inductions would show the increase as given in Table VII.

TABLE VII.

Values of η when Steel Contains 10 per cent Scale.

B	η of mixture ($x = 1.6$)	Ratio η to average η	Average ratio of sheet steel found from test values
7210	0.000721		1.00
9015	0.000716		1.01
10320	0.000716	1.00	1.04
12140	0.000716		1.13
13970	0.000737	1.03	1.24
15980	0.000842	1.17	
16850	0.000946	1.32	

Average η for first four points = 0.000717

The increase of η here given is not as great as found by test on sheet steel itself, but shows the same nature and rate of increase. In silicon sheet steel the scale and other impurities in the steel itself might easily be more than 10 per cent. of the volume, and the theoretical curve would thereby show greater increase of η and check the test results much closer.

TABLE VIII.

Values of Flux in Steel and in Scale for 20 per cent. Scale.

H	B		Flux in 0.8 cm.² of steel	Flux in 0.2 cm.² of scale	Total flux or apparent B of 1 cm.² of mixture
	In steel	In scale			
2	8,000	93	6,400	18	6,420
3	10,000	147	8,000	20	8,030
4	11,420	200	9,140	40	9,180
6	13,330	400	10,670	80	10,750
10	15,400	900	12,320	180	12,500
20	17,400	2,975	13,920	595	14,500
30	18,200	4,512	14,560	900	15,500

Table VIII gives similar calculations, assuming 20 per cent. of the cross-section area to be scale, and Table IX gives the hysteresis

TABLE IX.

Hysteresis Loss in Steel, Scale and Mixture with 20 per cent. Scale.

H	Hyst. in steel per cm.³	Hyst. in 0.8 cm.³ steel	Hyst. in scale per cm.³	Hist. in scale 0.2 cm.³	Hyst. in mixture	Log hyst.	Log apparent B
2	1183	947	29.4	6	953	2.979	3.808
3	1695	1358	62.0	12	1370	3.137	3.905
4	2090	1672	104	21	1690	3.228	3.963
6	2690	2153	318	64	2220	3.346	4.031
10	3390	2715	1130	226	2940	3.468	4.097
20	4130	3310	7800	1560	4870	3.688	4.161
30	4420	3540	14,950	2990	6530	3.815	4.190

For steel $\eta = 0.000675$

For scale $\eta = 0.0216$

loss in steel, scale, and the mixture, assuming 20 per cent. scale. Table X gives us values of η for the mixture, together with the amount of increase of η with increased induction. Comparing with test values of sheet steel, we find the increase of η with increased induction may be represented by steel and scale taken together, in which case the amount of scale is between 10 per cent. and 20 per cent., which we know represents the facts.

TABLE X.

Values of η When Steel Contains 20 per cent. Scale.

B	η	Ratio η to average η
6,420	0.000771	
8,030	0.000771	1.00
9,180	0.000771	
10,750	0.000786	1.02
12,500	0.000818	1.06
14,500	0.00105	1.36
15,500	0.00130	1.68

Average η for first three points $= 0.000771$

VI. Tests of Iron and Cobalt Separately and Together to Show Properties of Homogeneous and Heterogeneous Magnetic Materials.

In order to show more clearly the behavior of magnetic phenomena on homogeneous and heterogeneous materials, tests were made to determine the properties of as nearly pure materials as could be obtained. A solid ring of iron and a solid ring of cobalt were selected. Solid rings were tested to obtain most satisfactory magnetic flux paths and to eliminate scale as much as possible. The errors due to shape of specimen of the ring sample are not great and are practically the same for both specimens and are

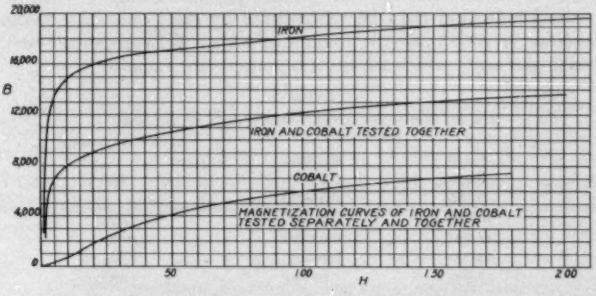
therefore negligible. The principal dimensions of the samples are as follows:

	Cobalt ring	Iron ring
Outer diameter	3.176 cm. (1.25 inch)	3.178 cm. (1.25 inch)
Inner diameter	2.223 cm. (0.875 inch)	2.223 cm. (0.875 inch)
Mean diameter	2.695 cm. (1.06 inch)	2.7005 cm. (1.06 inch)
Weight	31.15 grammes (0.068 pound)	28.01 grammes (0.062 pound)
Volume	3.534 cm.^{3} (0.216 cubic inch)	3.562 cm.^{3} (0.217 cubic inch)
Section	0.4165 cm.^{2} (0.0646 square inch)	0.415 cm.^{2} (0.0644 square inch)
Specific gravity	8.81	7.86

Magnetization and Reluctivity.

The test on the iron ring made by the usual ballistic galvanometer method gave results as shown in Table XI.

FIG. 10.



Results on the cobalt ring are given in Table XII, and in Table XIII we have test results made by taking both rings and testing them together as a single material.

The plotted results are given on Fig. 10. As the inductions at low values of H are required for analyses of hysteresis data, the lower portion of the magnetization curves are given on a larger scale in Fig. 11.

It would naturally be expected that, as the rings are of approximately the same section, the test on the two taken together would give an induction for any value of H which would be the mean of the values for the component parts. This may be shown by Table XIV, wherein test values from the iron, cobalt, and mix-

FIG. 11.

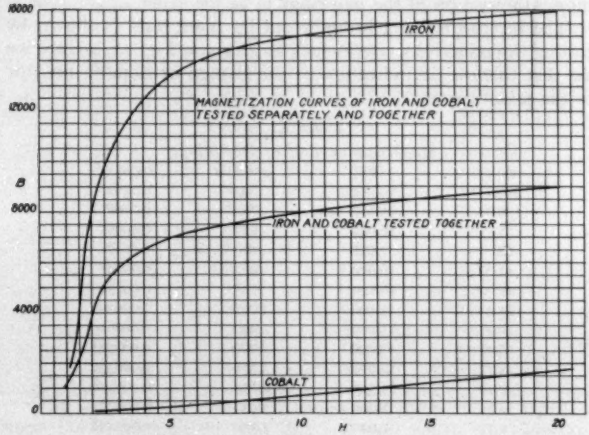
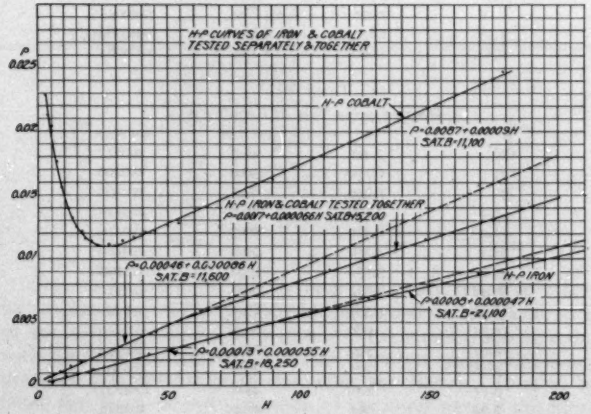

16000
12000
B
8000
4000
0
IRON
MAGNETIZATION CURVES OF IRON AND COBALT
TESTED SEPARATELY AND TOGETHER
IRON AND COBALT TESTED TOGETHER
COBALT
5
10
15
20
H

FIG. 12.


H-P CURVES OF IRON & COBALT
TESTED SEPARATELY & TOGETHER
P
0.025
0.02
0.015
0.01
0.005
0
H-P COBALT
P=0.0087+0.00009H
SAT.B=11,100
H-P IRON & COBALT TESTED TOGETHER
P=0.007+0.000066H SAT.B=5,200
P=0.00048+0.000096H
SAT.B=11,600
H-P IRON
P=0.0003+0.000047H
SAT.B=2,100
P=0.00013+0.000055H
SAT.B=18,250
0
50
100
150
200
H

ture are tabulated with the calculated density in the mixture, assuming the section of the two rings to be the same.

The interesting fact brought out by these tests is shown by plotting the reluctivity curves such as given on Fig. 12. Here we find that there is no indication of the change of slope in the line for the cobalt curve.

TABLE XI.

Magnetization Test of Iron Ring.

H	B	$\mu = B/H$	$\rho = H/B$
212	19,750	93	0.0107
170	19,280	114	0.0088
127	18,680	147	0.0068
84	17,930	213	0.0047
42	16,980	402	0.00247
21	16,130	765	0.00130
15.5	15,560	1,007	0.000995
10.4	15,010	1,450	0.000693
5.2	13,490	2,600	0.000385
4.17	12,670	3,350	0.000330
3.12	11,300	2,630	0.000276
2.09	8,220	3,930	0.000254
1.75	7,040	4,040	0.000248
1.67	5,370	4,040	0.000311
1.46	3,780	2,590	0.000388
1.36	2,920	2,150	0.000465
1.25	2,260	1,810	0.000555
1.10	1,830	1,670	0.000601
0.84	1,000	1,180	0.00084

TABLE XII.

Magnetization Test of Cobalt Ring.

H	B	$\mu = B/H$	$\rho = H/B$
179	7,440	41.5	0.0242
135	6,750	50.0	0.0200
91	5,650	62.5	0.0161
36.4	3,160	86.7	0.0115
27.2	2,460	90.5	0.0110
54.3	4,310	79.0	0.0126
45.0	3,732	83.0	0.0121
20.45	1,832	89.6	0.0112
16.28	1,385	83.1	0.0120
12.75	980	76.8	0.0130
9.10	592	65.1	0.0154
5.46	272	49.8	0.0201
3.12	140	45.0	0.0223
2.09	84	40.2	0.0249

TABLE XIII.

Magnetization Test of Iron Ring and Cobalt Ring Taken Together.

H	B	$\mu = B/H$	$\rho = H/B$
201	13,680	68	0.0147
186	13,490	73	0.0138
149	13,100	88	0.0114
112	12,450	111	0.0090
74	11,550	156	0.0064
45	10,510	234	0.00428
23.3	9,280	398	0.00252
15.8	8,600	544	0.00184
12.0	8,200	684	0.00147
8.15	7,610	934	0.00107
5.65	7,190	1,270	0.00079
4.52	6,770	1,495	0.00070
3.76	6,390	1,700	0.00059
3.01	5,780	1,920	0.00052
2.25	4,690	2,080	0.00048
1.88	3,650	1,940	0.00052
1.50	2,190	1,460	0.00069

The curve of the iron itself shows a slight bend or change of slope, indicating that the iron ring was very nearly homogeneous magnetically, but not entirely so.

TABLE XIV.

Comparison of Flux Densities in Iron, Cobalt and Mixture.

	B			
H	In iron by test	In cobalt by test	In both by test	Calculated average
150	19,000	7,000	13,000	13,000
100	18,200	5,900	12,200	12,050
50	17,100	4,100	10,700	10,600
20	16,000	1,800	9,000	8,900
10	14,800	700	7,900	7,750
5	13,400	300	6,900	6,850
2	8,000	100	4,000	4,000

Examining the curve for the iron and cobalt tested together, we see that at about $H = 55$ there is a sharp and decided bend, such as has been found in so many cases. This curve, while agreeing with the calculated results, is plotted from test results and is not deducted mathematically by assuming any theory. It is to be noted that the indicated saturation of the lower part of the curve

for iron and cobalt together is close to that indicated as the ultimate saturation of the cobalt. It is naturally somewhat higher, due to the effect of the iron.

Hysteresis Losses.

Hysteresis tests were made by means of a ballistic galvanometer. The results of the iron ring are given in Table XV.

TABLE XV.

Hysteresis Losses in an Iron Ring

(Losses in ergs per cm.³)

B	H	Hyst.	Log B	Log hyst.	η ($x = 1.6$ assumed)	
15,000	10.71	7,900	4.176	3.898	0.00164	
12,000	3.58	4,865	4.079	3.687	0.00145	Average 0.00145
10,000	2.455	3,510	4.000	3.545	0.00140	
6,000	1.758	1,614	3.778	3.308	0.00145	
4,000	1.505	873	3.602	2.941	0.00150	
1,000	0.890	73.8	3.000	1.868	0.00117	

The log h – log B curve is plotted on Fig. 13. The slope of the line, using all points, is 1.65; the upper points give nearer 1.6. The coefficient η is calculated on the basis of 1.6 for purposes of comparison. The results of cobalt ring are given in Table XVI.

TABLE XVI.

Hysteresis Losses in a Cobalt Ring.

(Losses in ergs per cm.³)

B	Hysteresis	Average hysteresis	Log B	Log hysteresis	η ($x = 1.6$ assumed)	
4000	11,020	11,000	3.603	4.041	0.0190	Average 0.0163
	10,950					
2000	3210	3150	3.301	3.498	0.0168	
	3080					
1000	810	830	3.000	2.919	0.0131	
	848					
500	203	203	2.699	2.308	0.0088	

The log h – log B curve is shown on Fig. 13: the slope of the line using all points is 1.85. Lack of time prohibited further tests to check these results. It has been shown that the exponent for cobalt is 1.60; and, while this figure would be more satisfactory to quote here, I prefer to give the data as obtained. This high value

of the exponent does not interfere with the present demonstration.

The results of hysteresis tests on the iron and cobalt rings together are given in Table XVII.

FIG. 13.

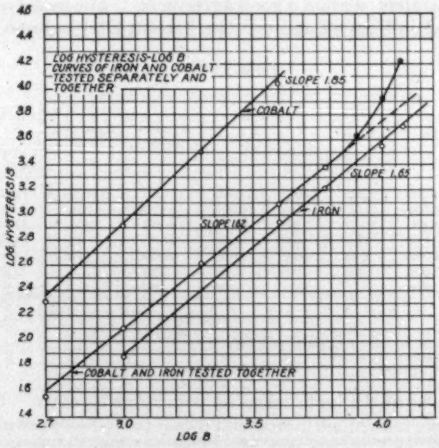


TABLE XVII.

Hysteresis Losses in an Iron and a Cobalt Ring Tested Together.

(Losses in ergs per cm.³)

B	Hyst.	H	Log B	Log hyst.	η ($B = 1.6$ assumed)	
12,000	17,470	101.1	4.079	4.242	0.00519	
10,000	8,975	38.6	4.000	3.953	0.00358	
8,000	4,110	11.2	3.903	3.614	0.00234	
6,000	2,360	3.41	3.778	3.373	0.00212	
4,000	1,228	2.055	3.602	3.089	0.00212	Average
2,000	409	1.523	3.301	2.612	0.00213	0.0021
1,000	126.2	1.191	3.000	2.102	0.00200	
500	35.9	0.885	2.699	1.556	0.00172	

Here we find that the plotted results on Fig. 13 give a line having a slope of 1.62 (or approximately 1.6) to $B = 6000$, beyond which we again find the indicated abnormal increase of hysteresis

loss. The deviation from the straight line is greater for this curve of the two metals than could possibly be considered as a characteristic of either of the metals themselves.

In order to show how the results on the two rings together compare with values calculated from the characteristic of the rings taken separately, we find a good agreement. The hysteresis losses are plotted on Figs. 14 and 15. In Table XVIII, column 1 shows

Table XVIII.

H	B_{Fe}	B_{Co}	B mixture		Hysteresis Fe	Hysteresis Co	Hysteresis of mixture	
			Calculated	Test			Calculated	Test
101.1	18200	5900	12050	12000	11900*	23100†	17500	17470
38.6	16800	3300	10050	10000	9770‡	7750	8760	8975
11.2	15100	800	7950	8000	8000	500	4250	4110
3.41	11700	150	5925	6000	4600	25	2315	2360
2.055	8000	100	4050	4000	2460	10	1235	1228
1.52	4000	50	2025	2000	873	...	435	409
1.191	2200	..	1100	1000	300	...	150	126.2
0.885	.....	..	....	500	203	...	100	35.9

* Calculated by extrapolation of $B-\eta$ curve. η taken as 0.0018.
† Calculated by extrapolation of $\eta=0.021$.
‡ Calculated by extrapolation of $\eta=0.0017$.
All other results from results Figs. 14 and 15.

the H values of the loops taken on both rings together. Columns 2 and 3 give inductions in iron and cobalt taken from the magnetizing curves on Figs. 10 and 11. The calculated density and the observed density for the loops are given in columns 4 and 5. Columns 6 and 7 give hysteresis results in iron and cobalt at their respective densities, taken from Figs. 14 and 15. Column 8 gives calculated hysteresis losses of the mixture, they being the mean of columns 6 and 7. Column 9 gives the observed hysteresis loss of the mixture from the tests.

VII. Application of Data in Calculating Magnetic Losses.

We have shown that the usual deviations from the reluctivity and hysteresis laws may be accounted for by the fact that the materials are not homogeneous. It therefore is evident that to expect the laws to hold for all mixtures is as inconsistent as to take the compressive strength of a brick and use that figure to calculate the strength of a brick wall having, say, 10 per cent. mortar.

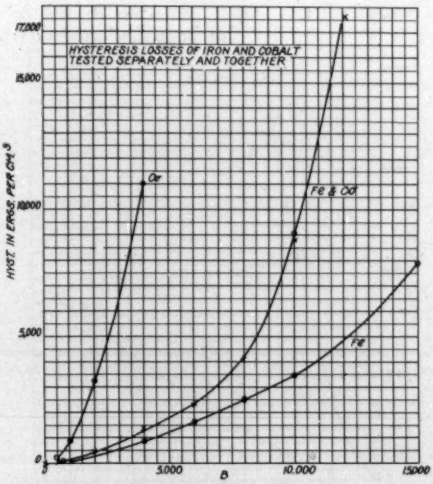
In the case of sheet steel, for any given magnetization the per-

meability and hysteresis losses must be calculated for steel and scale separately and combined in correct proportions, especially if accuracy is desired at high inductions.

For purposes of illustration let us assume that it is desired to obtain the ratio of hysteresis losses in silicon steel at inductions of $B = 15{,}000$ and $B = 10{,}000$.

If the material in question were homogeneous throughout and

FIG. 14.



the hysteresis loss followed the Steinmetz law, between $B = 15{,}000$ and $B = 10{,}000$, the ratio of hysteresis loss, R_h, would be:

$$R_h = \left(\frac{15{,}000}{10{,}000}\right)^{1.6} = 1.91.$$

Assuming 10 per cent. scale, the densities in the iron, the scale, and the mixture may be taken for various values of H from Table V.

Plotting a curve, Fig. 16, giving relation of apparent B in the material and the B in scale, and finding therefrom the actual flux density in the steel itself, we obtain values in Table XIX.

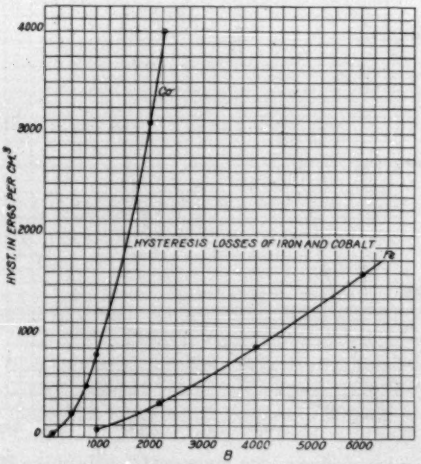
TABLE XIX.

Distribution of Flux Densities in Steel and Scale.

B (apparent)	B in scale	Flux in 0.1 cm.² of scale	Flux in 0.9 cm.² of steel	B in steel
15,000	1,500	150	14,850	16,500
10,000	200	20	9,980	11,090

Table XIX shows that when testing at $B = 15{,}000$ and $B = 10{,}000$ the actual density in the steel is 16,500 and 11,100, and the

FIG. 15.



ratio of densities for the scale is very much greater than the ratio of apparent densities.

Assuming the 1.6 law to hold rigidly for both steel and scale, and taking the values of Table XIX, we should expect, when testing at $B = 15{,}000$ and $B = 10{,}000$, ratios as follows:

Hyteresis ratio for steel:

$$R_h = \left(\frac{16{,}500}{11{,}090}\right)^{1.6} = 1.89.$$

Hysteresis ratio for scale:

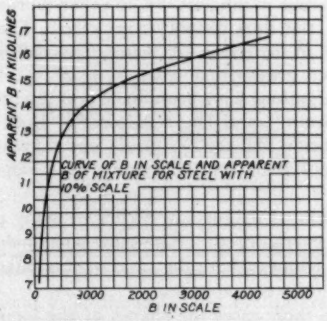
$$R_A = \left(\frac{150}{20}\right)^{1.6} = 25.$$

For 90 per cent. steel and 10 per cent. scale the hysteresis ratio of the mixture would be:

$$R_A = \frac{(90 \times 1.89) + (10 \times 25)}{100} = 4.20.$$

While our data on scale are limited, and the varying percentages of scale would affect results, yet the figures obtained represent test results reasonably well.

FIG. 16.



VIII. Investigation to Determine Losses in Unsymmetrical Loops.

Shortly after the announcement of the 1.6 law the statement was made that "the energy dissipated by hysteresis depends only upon the difference of the limiting values of magnetic induction, between which the magnetic cycle is performed, but not upon their absolute values, so that the energy dissipated by hysteresis is the same so long as the amplitude of the magnetic cycle is the same." [9] This has been written as

$$= h \left(\frac{B_1 - B_2}{2}\right)^{1.6}$$

[9] *Trans. A. I. E. E.*, vol. ix, 1892, p. 633

where B_1 and B_2 are the values between which the magnetism varies. Tests were made which apparently justified and substantiated this statement, and the results were published.

In these tests the range of flux values was comparatively small as compared with the range of values of the mean inductions, and the materials employed were magnetically hard and characterized by high hysteresis loss.

It has recently been observed that when materials are taken through unsymmetrical hysteresis cycles there is, contrary to earlier writers, apparently more energy dissipated than when taken through the symmetrical loop of the same amplitude. By an unsymmetrical loop is meant the hysteresis loop obtained when the magnetism is carried through a cycle in which the limiting values of flux are different in amount, or, in other words, in which the mean value of the flux differs from zero. The recent statements, then, are to the effect that when B_2 is different in amount from B_1 the loss is greater than when $B_2 = -B$.

Some investigations have been made and the results published by Mr. Rosenbaum[10] and Dr. F. Holm.[11] Both investigations led to the conclusion that the hysteresis loss is greater for the unsymmetrical loops than for the symmetrical loops of the same amplitude.

Such variation of magnetism occurs in many places, such as in an inductor generator, etc. The same phenomena occur in the field cores of machines where the ratio of flux change is so small that the loss is not a consideration.

However, in these cases the shapes of the loops are of value in determining the regulation of machines in which the magnetic cycle of the field cores is a determining factor.

The unsymmetrical hysteresis loop is also in evidence in all material magnetized by current from a rectifier, etc.; in short, in all circuits where alternating current and direct current are superimposed. A specific case of interest is the well-known fact that core losses of certain machines have been found to exceed calculated values, unless percentages are added. The fact that high-frequency flux ripples in the teeth give a higher hysteresis loss than the same flux change with zero as a mean value of in-

[10] *Jour. I. E. E.*, vol. 48, 1912, pp. 534–545.
[11] *Zeit. des ver. deut. Ing.*, vol. 56, 1912, pp. 1746–1751.

duction would in part account for this additional loss. This is especially noticeable in the case of induction machines.

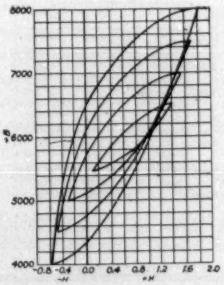
In the present investigation tests were made which led to these interesting deductions:

1. The hysteresis loss in an unsymmetrical loop is greater than the loss in a symmetrical loop of the same difference of limiting values of flux.[12]

2. Within the limits of the tests, the losses of loops having the same difference of limiting values of flux were found to increase with a definite power of the average or mean flux density.

3. The increased loss as a definite power of the mean flux

FIG. 17.



Group of unsymmetrical loops about a common centre. $B_m = 6000$. Medium silicon steel.

density was found to be the same for any difference of limiting flux values or range of the loops.

4. With any given value of mean density the increased losses with increased range were found to increase as definite power of the range, irrespective of the mean value of density.

Fig. 17 shows a group of unsymmetrical loops about a common centre, $B_m = 6000$.

Fig. 18 shows a group of loops of the same range of flux change, but having different values of mean induction.

We have found that we could write an equation to express the loss in any loop. The general equation is:

$$h = (\eta + \alpha B_m{}^{\nu}) B^{x}$$

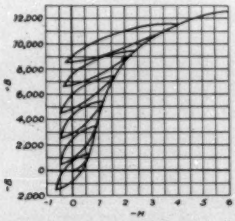
[12] This has been again confirmed by a valuable investigation made by Messrs. L. W. Chubb and T. Spooner. See *Proc. A. I. E. E.*, October, 1915, pp. 2321–2342.

wherein η and x are the constants of the Steinmetz law, α is a coefficient depending upon the material, and y a power of the mean density. Tests satisfied the equation in the form:

$$h = (\eta + \alpha B_m^{1.9}) B^{1.6}$$

The details of this portion of our general investigation have been published elsewhere [13] and need not be reproduced here; it is sufficient to say that with an accumulation of more data the equation for any loop which we give may or may not be verified as a law. However, it seems very definitely shown the loss increases as the mean induction is raised.

FIG. 18.



Group of unsymmetrical hysteresis loops. Medium silicon steel. Loops of amplitude. $B = \infty$ 1500 with various values of B_m.

CONCLUSIONS.

From this investigation we find additional evidences that the hysteresis law as given by Dr. Steinmetz in 1892 is confirmed, and his equation $h = \eta B^{1.6}$ correctly represents the hysteresis loss over a wide range of densities up to the highest recorded for pure or magnetically homogeneous materials. While some results which have been published showing much greater losses at high induction than given by the law are incorrect, due to erroneous calculations, however, most results showing greater losses at high inductions are taken from test data obtained on heterogeneous material whose component parts, if tested separately, would follow the law.

It may be pointed out that if two components of a heterogeneous material followed the 1.6 law, and with increasing H, the induction in the two increased at the same rate, the resultant

[13] *Proc. A. I. E. E.*, October, 1915, pp. 2275–2297.

must also show an increased loss following the 1.6 law. The deviations noted are due to the fact that with increasing magnetization the induction in two materials does *not* increase at the same rate throughout. Therefore, as they do not, the measured hysteresis loss could not be expected to follow any law. The difference in materials employed and the difference of their respective volumes may and probably does introduce an infinite variety of possible combinations which prohibits a rational law.

The same reasoning applies to the reluctivity law of Kennelly, which is also confirmed by this investigation.

Test results have been given in considerable detail for the benefit of any who may be interested and may wish to draw conclusions other than those set forth in this paper.

Why the hysteresis loss increases as the 1.6 power of the density has, to our knowledge, never been explained. That it cannot hold at very low densities has been shown by Dr. Steinmetz himself. The fact remains, however, that our knowledge has been greatly augmented by the announcement of this useful discovery, and careful research is still showing that the law as stated correctly represents the hysteresis losses in magnetic materials.

In conclusion, the author desires to acknowledge much excellent coöperation. The work was attempted at the instigation of Dr. C. P. Steinmetz, for whose interest and assistance the author is greatly indebted. The writer also desires to thank Mr. L. T. Robinson for helpful suggestions and for placing the facilities of his laboratory at the author's disposal. In this laboratory much of the testing was done by Mr. S. L. Gokhale. The testing of steel scale was done in Mr. A. McK. Gifford's laboratory by Mr. Max. G. Newman.

Acknowledgment is also due to Mr. J. P. Duncombe for much valuable assistance throughout the process of this investigation.

SCHENECTADY, N. Y.,
November 1, 1915.

APPENDIX.

IX. Additional Properties of Scale from Silicon Steel.[14]

While tests described in Section IV of this paper were being made it seemed feasible to take the opportunity to make a further

[14] Some results of the investigation of steel scale have been used by the author in connection with a graduate thesis submitted to the University of Illinois and are published here with the permission of that institution.

study of the properties of scale as a matter of general interest and also as it has possibilities as a material for certain constructions.

Skin Effect.

The fact that scale is thin and has fairly good permeability and high resistivity places it as a desirable material for cores in machines and transformers of high frequency. The resistivity being high and the permeability being lower than that of ordinary steel give deeper penetration as regards skin effect, which is also an important consideration. Assuming the scale as carrying flux, the effective depth of penetration, l_p in cm., would be, according to the Steinmetz formula:

$$l_p = \frac{3570}{\sqrt{\lambda \mu f}}$$

wherein

λ = electrical conductivity.
μ = magnetic permeability.
f = frequency in cycles per sec.

The permeability varies, of course, with the flux density. We may assume for permeability a value $\mu = 60$. The average conductivity is $\frac{1}{126.2} + 10_6 = 7920$. At 10,000 cycles

$$l_p = \frac{3.570}{\sqrt{7920 \times 60 \times 10{,}000}} = 0.0518 \text{ cm.}$$

Assuming the thickness of the scale is 0.0064 cm. l_0, or ½ of the thickness, is 0.0032. This shows the penetration l_p is much greater than ½ thickness l_0, therefore there is no appreciable skin effect at 10,000 cycles. The maximum allowable thickness of scale which has no appreciable skin effect at 10,000 cycles would be 0.1036 cm. (0.0408 inch). The maximum frequency at which no appreciable skin effect would be in evidence would be found by letting $l_p = 0.0032$ and solving for f, which gives 2,600,000 cycles.

Properties at High Frequency.

Punchings of the same size as described in Section IV, but of less weight, were built up into a test sample for determining the properties at high frequency. A test was made at 10,000 cycles, but the results obtained were not at all consistent. Tests were

made at 97,000 cycles and 50,000 cycles, and repeated trials gave close checks with the first tests. The results are given on Fig. 19, from which Table XX was computed.

FIG. 19.

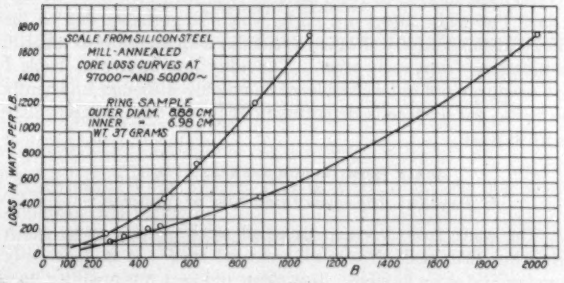


TABLE XX.

Losses in Scale from Silicon Steel at High Frequencies.

	Hyst. loss watts per pound		Loss per cycle		Loss per cycle 97,000 cycles	
B	97,000 cycles	50,000 cycles	97,000 cycles	50,000 cycles	Hyst.	Eddy
1,000	1,540	570	0.0159	0.0114	0.0066	0.0093
900	1,290	490	0.0133	0.0098	0.0061	0.0072
800	1,060	420	0.0109	0.0084	0.0057	0.0052
700	860	360	0.00887	0.0072	0.00542	0.00345
600	670	300	0.00691	0.0060	0.00503	0.00188
500	500	250	0.00515	0.0050	0.00484	0.0003

B	Hyst. in ergs per cycle per cm.^{3}	η ($x = 1.6$ assumed)
1,000	806	0.0128
900	745	0.0142
800	696	0.0155
700	662	0.0182
600	615	0.0223
500	590	0.0283

It will be remembered that the value of η taken from the 60- and 30-cycle core-loss curves and the hysteresis loops gave a value of 0.0216.

The results are practically self-explanatory. Values of η, assuming $x = 1.6$, are given, although it would not be expected that the 1.6 law would hold rigidly at these low inductions.

Eddy-current Losses.

For the core-loss curves the eddy losses were found to be as shown in Table I. These losses are not consistent, as good results would not be expected by the method of test used and the high hysteresis to be subtracted from the core loss, which is mostly hysteresis. The eddy losses are high, which is probably due to the fact that the sample was taken as a bulk, with no effort to insulate laminations from each other. The eddy loss figures in Table I are therefore not to be considered as reliable, although sufficiently so to use for hysteresis determinations in the table wherein they were so used.

SCALE FROM VACUUM-ANNEALED STEEL.

Physical Appearance and Size of Samples.

The scale from vacuum-annealed steel appears to be much smoother than scale from mill-annealed steel. It is apparently tougher and more flexible. It is clean and very much whiter than the usual scale. One side is a dull grayish white, while the other side has a brighter shine and closely resembles silver. Two samples were tested, both of which were made up of ring punchings 0.0056 cm. (0.0022 inch) thick. One sample measured, outer diameter 15.25 cm. (6 inches), inner diameter 10.15 cm. (4 inches); the other sample was, outer diameter 8.89 cm. (3.5 inches), inner diameter 6.86 cm. (2.7 inches).

Specific Gravity.

The first determinations gave a specific gravity of 5.54 for both mill-annealed and vacuum-annealed scale. Core-loss and hysteresis tests were calculated on this basis. Subsequent study of the material led to the belief that this figure was low for scale from vacuum-annealed steel, and the analyses were repeated. The figure 5.54 was confirmed for the mill-annealed scale, but the vacuum-annealed product gave a more consistent figure of 6.07 at 15.5° C. The gravity may therefore be considered approximately 6.0. The core-loss curves and hysteresis loops have not been altered, as the results in ergs, upon which analyses of results are based, are the correct figures.

The magnetization curves also include assumptions of specific gravity = 5.54, but the error is much less than the variation in

material, and consequently allowed to stand as originally calculated. The steel from which the scale was taken has a specific gravity of practically 7.5 after vacuum anneal as well as after mill anneal.

Chemical Analysis.

The first analysis of this material gave the following results:

Si	7.03
S	0.148
Mn	0.43
C	0.054

An analysis for oxygen gave 0.73 per cent., but this is undoubtedly not correct.

A later and reliable analysis gave:

Si	5.72	5.48
S	0.113	0.114
P	0.019	0.018
Mn	0.20	0.20
C	0.180	0.142
Fe	78.30	78.50
Total	84.532	84.454

The missing 15 per cent. is doubtless oxygen, as most of the silicon and some of the iron are present in the oxide state.

Resistivity.

Samples of vacuum-annealed scale were found to have an average resistivity of 53.1 microhms per cm.^{3} at 25° C. The individual values varied from 30 to 78. Previous tests on this material gave from 60 to 65 microhms, which is within the limits of the tests on the larger number of samples. These values are on the same order as those obtained from the steel itself.

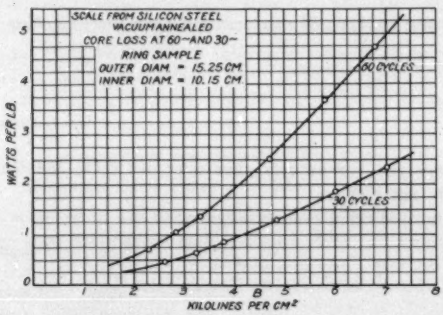
Temperature Coefficient.

This material was measured for temperature coefficient. The average figure given was 0.0059.

Core Loss.

Core-loss curves were made on the 15.25 cm. × 10.15 cm. sample at 60 cycles and 30 cycles from $B = 2500$ to $B = 7000$. Results are shown in Fig. 20. Data derived from these curves

FIG. 20.



are tabulated with the discussion of the hysteresis loss. A previous core-loss test at 60 cycles was found to agree with the 60-cycle curve in Fig. 20.

Hysteresis Loss.

The hysteresis loss at various densities was determined by the separation method. This was done by taking values from the core-loss curves at 60 cycles and 30 cycles and obtaining the loss per cycle as shown in Table XXI.

TABLE XXI.

Losses in Scale from Vacuum-annealed Sheet Steel.

B	Total losses		Loss per cycle		Loss per cycle at 60 cycles	
	60 cycles	30 cycles	60 cycles	30 cycles	Hyst.	Eddy
7500	5.52	2.58	0.0092	0.0860	0.0800	0.0120
6000	3.82	1.85	0.0636	0.0617	0.0598	0.0038
5000	2.80	1.38	0.0466	0.0460	0.0454	0.0012
4000	1.90	0.95	0.0317	0.0317	0.0317	
3000	1.10	0.56	0.0183	0.0187	0.0185	
2500	0.80	0.40	0.0133	0.0133	0.0133	

From the above table the hysteresis losses in ergs per cm.^{3} were calculated and the logarithms of the losses and of the inductions taken as shown in Table XXII.

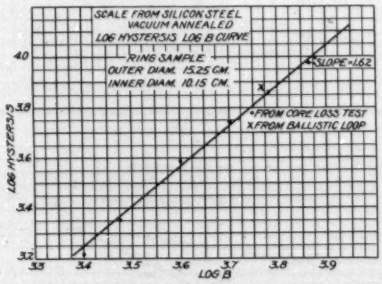
TABLE XXII.

Hysteresis Loss in Scale from Vacuum-annealed Sheet Steel.

B	Hyst. ergs per cm.³	Log B	Log hyst.	η ($x = 1.6$ assumed)
7500	9770	3.875	3.990	0.00616
6000	7310	3.778	3.864	0.00656
5000	5550	3.699	3.744	0.00670
4000	3870	3.602	3.588	0.00688
3000	2260	3.477	3.354	0.00618
2500	1625	3.398	3.211	0.00595
			Average	0.00637

A plot of the log hysteresis – log B is shown in Fig. 21. Taking the five upper points of the curve, the slope given by the $\Sigma\Delta$ method is 1.62. Assuming $x = 1.6$, we obtain for η an average of 0.00637. For the five highest points average $\eta = 0.00646$. Here again we may note the insistence of the Steinmetz formula.

FIG. 21.



A loop was taken at B maximum = 5876, as shown in Fig. 22. The loss was found to be 7625 ergs per cm.³ Assuming $x = 1.6$, $\eta = 0.00711$. We may therefore assume the hysteresis of this material to be approximately $h = 0.007\ B^{1.6}$, or about 30 per cent. of that scale from mill-annealed material. That the hysteresis loss of silicon sheet steel may be lowered by means of vacuum anneal is a well-known fact.

Eddy-current Losses.

Table XXI shows eddy-current losses. These figures are not reliable and apply to a bulk of material rather than insulated sheets, and should not be considered as representing the material with any degree of accuracy.

FIG. 22.

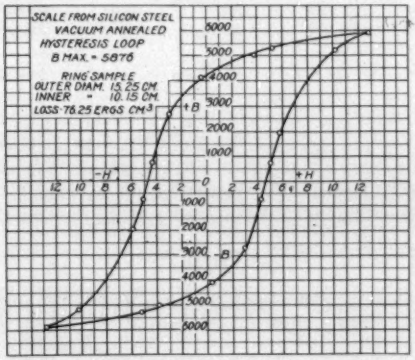
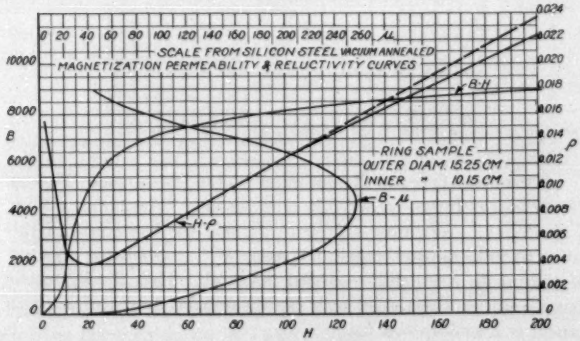


FIG. 23.



Magnetization, Permeability, and Reluctivity.

The two samples previously described were tested for magnetization curves. Results of the tests on the 15.25 cm. × 10.15 cm. ring are given in Table XXIII. The magnetization, permeability, and reluctivity curves are plotted on Fig. 23. The reluctivity curve is a straight line from $H = 30$ to $H = 90$, and also a straight line from $H = 90$ to $H = 200$, the limit of the test. The equations of the lines by the $\Sigma\Delta$ method are:

From $H = 30$ to $H = 90$:
$$\rho = 0.0014 + 0.00011\ H$$
Saturation $B = 9000$
From $H = 90$ on:
$$\rho = 0.0028 + 0.000097\ H$$
Saturation $B = 10{,}300$

The equations of the magnetization curves are therefore:

From $H = 30$ to $H = 90$:
$$B = \frac{H}{0.0014 + 0.00011\ H}$$
From $H = 90$ on:
$$B = \frac{H}{0.0028 + 0.000097\ H}$$

The maximum permeability of the sample is about 257 at $B = 4500$.

FIG. 24.

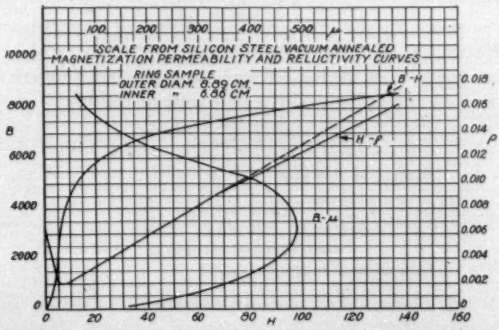


TABLE XXIII.

Magnetization Data of Scale from Vacuum-annealed Sheet Steel.

H	B	$\mu = B/H$	$\rho = H/B$
200	8980	44	0.0222
150	8640	57	0.0174
140	8530	60	0.0164
130	8430	64	0.0156
120	8375	69	0.0143
110	8250	74	0.0133
100	8170	81	0.0122
90	8010	88	0.0112
80	7920	98	0.0101
70	7708	109	0.0091
60	7499	124	0.0080
50	7245	144	0.0069
40	6876	171	0.0058
30	6337	210	0.0048
20	5060	253	0.0040
10	1919	192	0.0053
5	428	86	0.0116
3	210.2	70	0.0143
2	131.2	65.6	0.0152
1.5	55.3	36.9	0.0272
1.25	49.0	39.1	0.0255
1.0	37.2	37.2	0.0269
0.5	16.7	37.0	0.0269
0.3	10.8	35.9	0.0278

Tests were made on the 8.89 cm. × 6.86 cm. ring which showed better permeability than the previous results. The data are given in Table XXIV, and plotted in Fig. 24.

The equations of the reluctivity and magnetization were found as for the other samples. The results were as follows:

From $H = 10$ to $H = 70$:

$$\rho = 0.00101 + 0.000121\,H$$

Saturation $B = 8300$

$$B = \frac{H}{0.00101 + 0.000121\,H}$$

From $H = 70$ to $H = 137$. (Limit of test):

$$\rho = 0.00215 + 0.000103\,H$$

Saturation $B = 9700$

$$B = \frac{H}{0.00215 + 0.000103\,H}$$

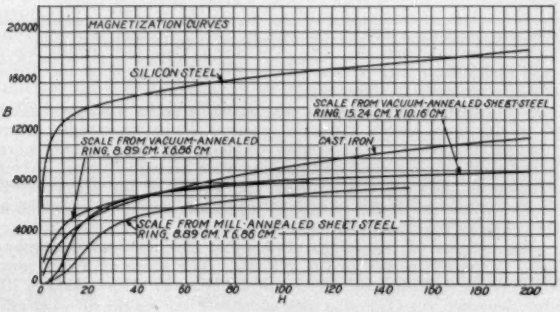
TABLE XXIV.

Magnetization Data of Scale from Vacuum-annealed Sheet Steel —Second Sample.

H	B	$\mu = B/H$	$\rho = H/B$
137	8560	61	0.0160
100	8074	81	0.0124
90	7908	88	0.0114
80	7749	96	0.0103
70	7529	110	0.0093
60	7374	124	0.0081
50	7124	144	0.0070
40	6829	170	0.0059
30	6440	214	0.0047
20	5880	294	0.0034
15	5405	359	0.0028
10	4570	457	0.0022
7.5	3662	487	0.0021
5.0	2385	476	0.0022
2.0	461.9	230	0.0043
1.5	325.5	216	0.0046
1.0	165.8	165	0.0060
0.5	80.7	160	0.0062

The maximum permeability of this sample is about 490 at $B = 3500$.

FIG. 25.



Skin Effect.

The skin effect of this material is more marked than for the mill-annealed product, because of its lower resistivity and high

permeability. Considering the permeability $\mu = 200$ and the conductivity 18,800, the penetration l_p at 10,000 cycles would be

$$l_p = \frac{3570}{\sqrt{18{,}800 \times 200 \times 10{,}000}} = 0.0194 \text{ cm.}$$

Assuming the thickness of the scales as 0.0056 cm., l_0, or ½ of the thickness, is 0.0028. Therefore there is no appreciable skin effect at 10,000 cycles. The maximum allowable thickness of scale which has no appreciable skin effect at 10,000 cycles would be 0.0388 cm. (0.015 inch). The maximum frequency at which no appreciable skin effect would be in evidence would be found by letting $l_p = 0.0028$ and solving for f, which gives 480,000 cycles.

Considering the magnetization curves, the values of η, and the resistivity, we find scale has those properties on much the same order as found for cast iron. Magnetization curves of silicon steel, cast iron, and the samples of scale are shown on Fig. 25.

On the Cooling of Cylinders in a Stream of Air. P. J. A. HUGHES. (*Philosophical Magazine*, vol. 31, No. 182, February, 1916.)—The interchange of heat between a solid and a moving stream of gas is a subject of considerable technical importance. A considerable amount of work has been done on the cooling of thin wires in a current of air, mainly with the object of constructing instruments for the measurement of air-velocity. These experiments have shown that the heat lost by the wire is proportional to the difference of temperature and to the square-root of the velocity. There are, however, no data available relating to the convection of heat from bodies of large diameters. The experiments described in this paper were undertaken with a view of throwing some light on the problem of convection in these cases.

The measurements were carried out on a series of copper tubes all of the same length but with external diameters ranging from 0.433 cm. to 5.06 cm. These tubes, of about a metre in length, were placed vertically in a wind-channel, and were heated by steam. After a steady temperature was attained, the weight of the water which condensed in the cylinder in a given time measured the heat which it lost through convection and radiation.

An analysis of the results shows that the heat-loss is proportional to the n^{th} power of the velocity. The value of n increases from 0.5 for cylinders of very small diameter to 1 for cylinders of large diameter, thus bringing into agreement the results of other experimenters on large bodies and on wires. Experiments on tubes of stream-line section showed losses slightly greater than those from a circular tube of the same total area, but much greater than from a circular tube of the same width or the same air resistance.

COAL-GAS RESIDUALS AND THEIR APPLICATION.*

BY

FRED. H. WAGNER, M.E.,

Chief Engineer, The Bartlett Hayward Company.
Gas By-product Lecturer, Johns Hopkins University.
Member of the Institute.

THE destructive distillation of coal, as practised to-day, may be divided into two classes, the first being that practised in gas works, the second being the one practised by the coke oven operator. The latter method of distillation, or carbonization, may also be subdivided into two classes, or distillation with by-product recovery, and bee-hive oven distillation; as the latter yields no other product than coke, it will not be given any further consideration.

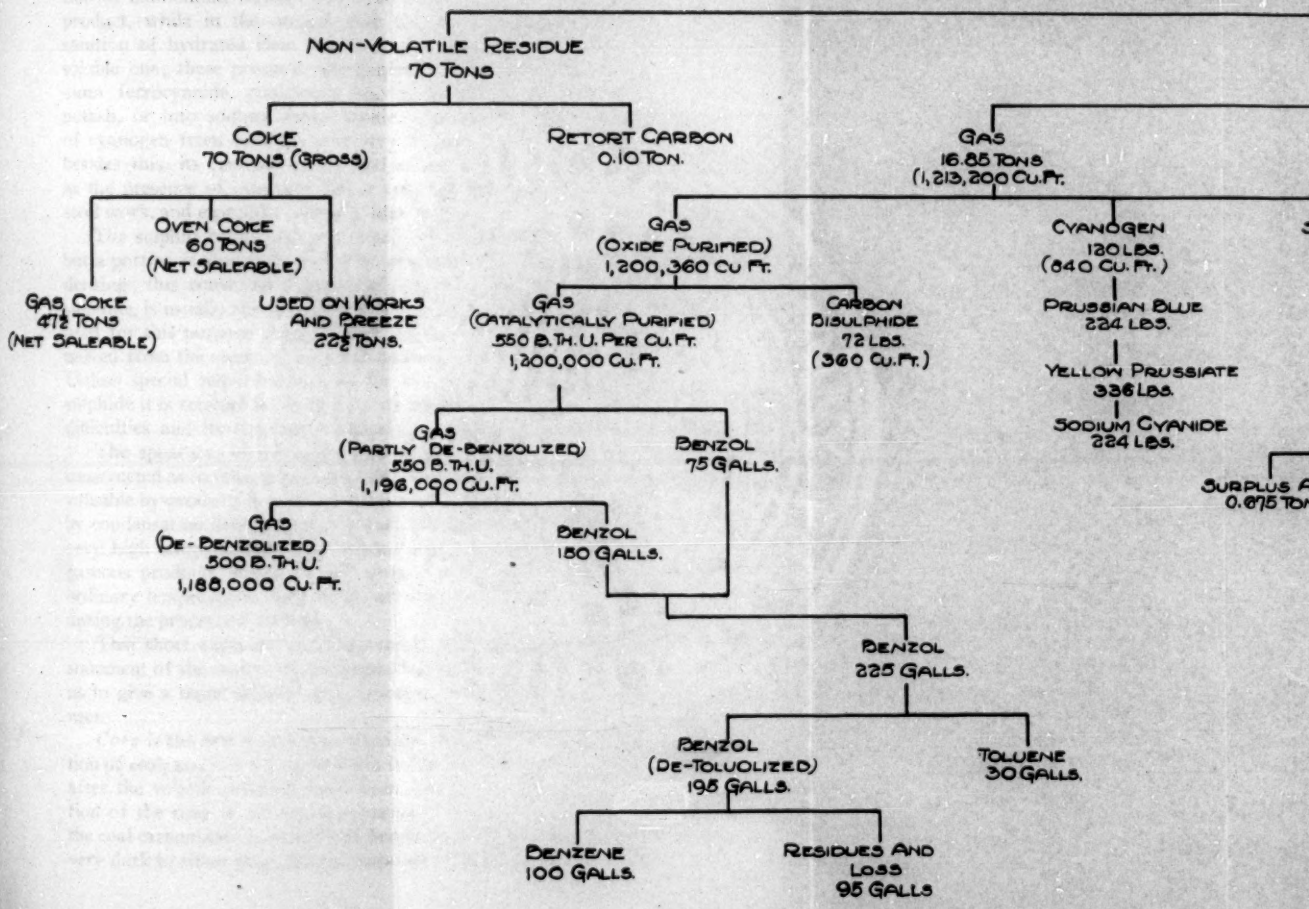
These two classes of distillation, or carbonization, lead to two very different methods of operation; the object of the gas works operator is to produce a maximum yield of gas possessing certain required qualities, such as candle-power and thermal value, with the recovery of certain by-products, while the object of the coke oven operator is to produce a maximum of low-volatile coke, the recovery of by-products, in some instances, being entirely neglected.

The quantity of gas produced, as well as the production of coke and other by-products, is entirely dependent upon the character of the coal distilled, as well as on the character of the carbonizing plant. Gas intended for cooking or illuminating purposes must possess certain characteristics, and must consequently be purified, as the crude gas contains substances which are of a harmful character, and, if retained in the gas, these substances would be liberated during combustion; but these substances all possess a commercial value, and, with the exception of coke and retort graphite, the by-products secured from a gas works are therefore due to the necessity of cleaning the gas before it can be used for domestic purposes.

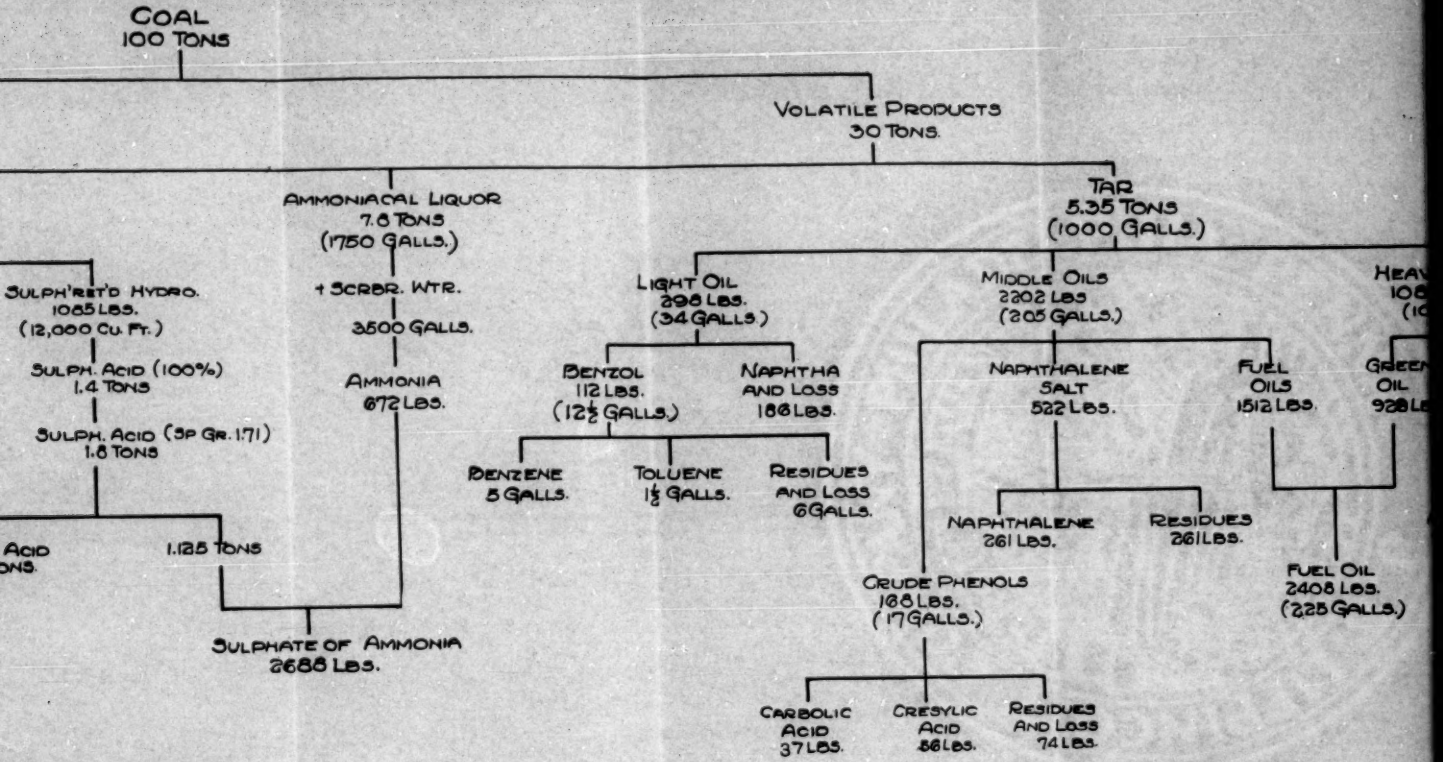
The principal by-products consist of coke, retort graphite, tar,

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, January 6, 1916.

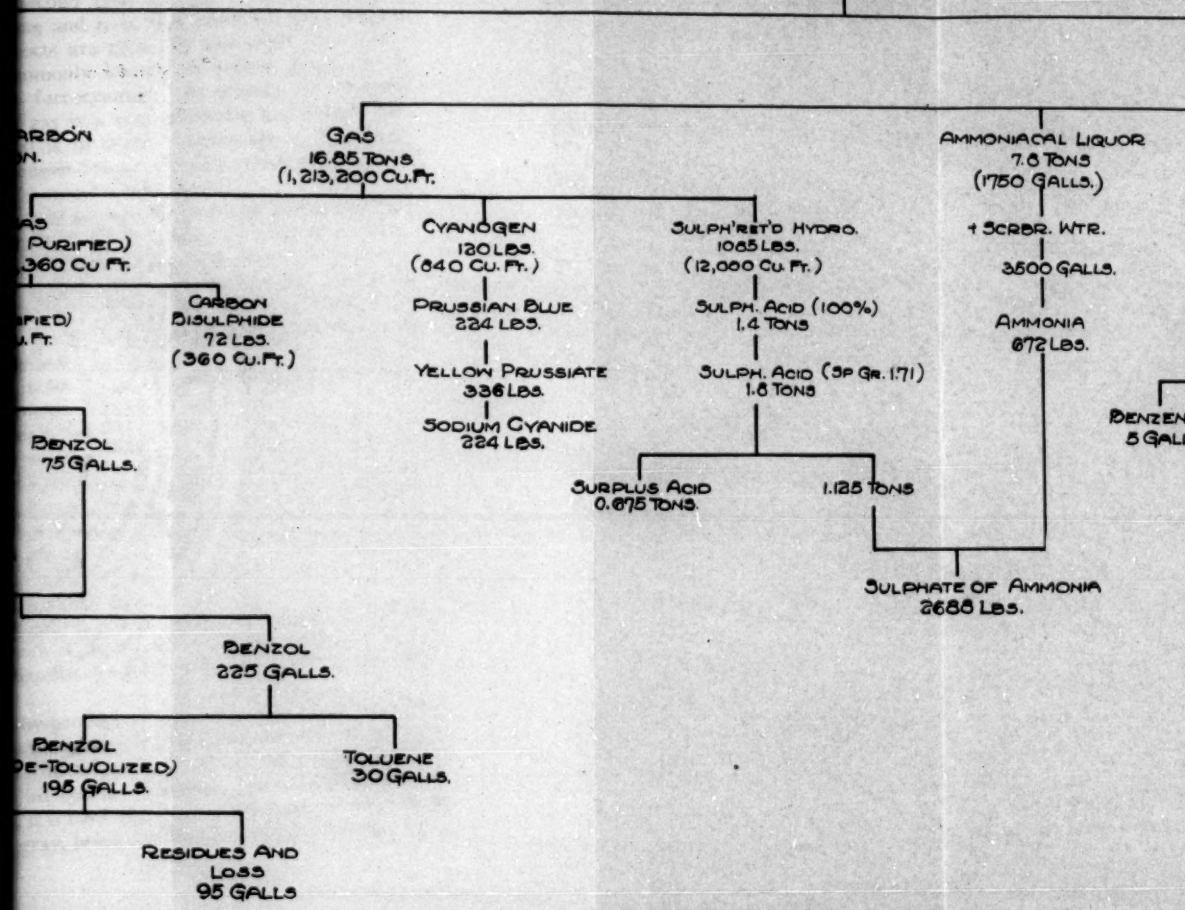
PRODUCTS FROM THE DISTI



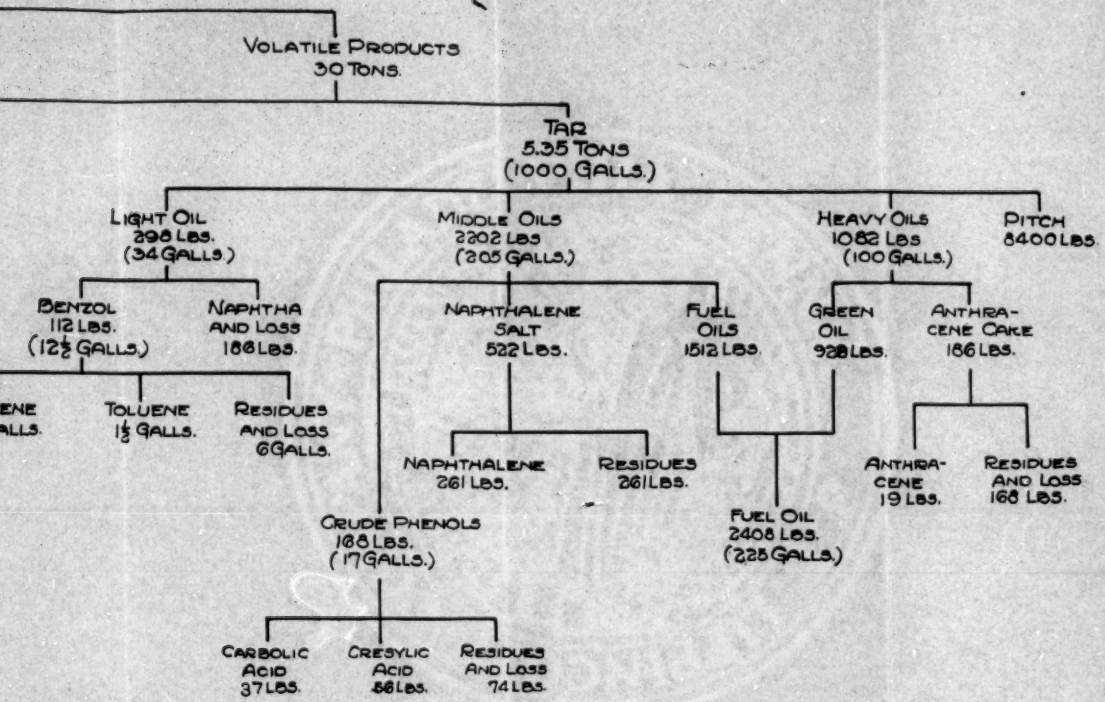
ILLATION OF 100 TONS OF BITUMINOUS COAL.

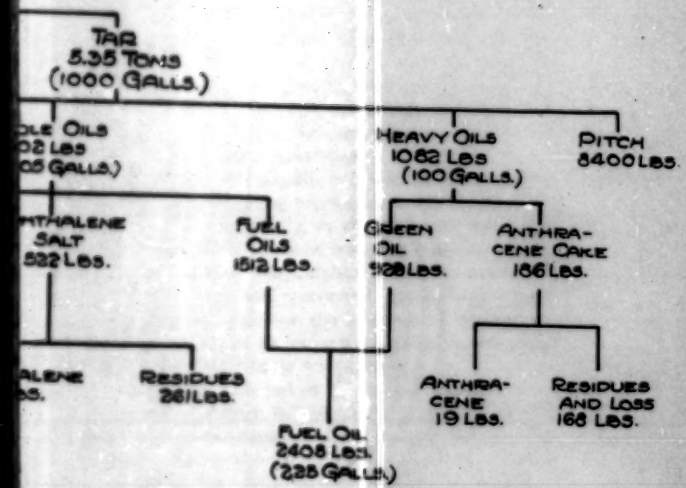


PRODUCTS FROM THE DISTILLATION OF 100 TONS OF BITUMINOUS C



COAL.


VOLATILE PRODUCTS
30 TONS.
TAR
5.35 TONS
(1000 GALLS.)
LIGHT OIL
298 LBS.
(34 GALLS)
MIDDLE OILS
2202 LBS
(205 GALLS.)
HEAVY OILS
1082 LBS
(100 GALLS.)
PITCH
8400 LBS.
BENZOL
112 LBS.
(12½ GALLS.)
NAPHTHA
AND LOSS
186 LBS.
NAPHTHALENE
SALT
522 LBS.
FUEL
OILS
1512 LBS.
GREEN
OIL
928 LBS.
ANTHRA-
CENE CAKE
186 LBS.
ENE
ALLS.
TOLUENE
1½ GALLS.
RESIDUES
AND LOSS
6 GALLS.
NAPHTHALENE
261 LBS.
RESIDUES
261 LBS.
ANTHRA-
CENE
19 LBS.
RESIDUES
AND LOSS
168 LBS.
CRUDE PHENOLS
188 LBS.
(17 GALLS.)
FUEL OIL
2408 LBS.
(225 GALLS.)
CARBOLIC
ACID
37 LBS.
CRESYLIC
ACID
86 LBS.
RESIDUES
AND LOSS
74 LBS.


TAR
5.35 TONS
(1000 GALLS.)
HEAVY OILS
1082 LBS
(100 GALLS.)
PITCH
8400 LBS.
FUEL
OILS
1512 LBS.
ANTHRA-
CENE CAKE
186 LBS.
RESIDUES
261 LBS.
ANTHRA-
CENE
19 LBS.
RESIDUES
AND LOSS
168 LBS.
FUEL OIL
2408 LBS.
(225 GALLS.)

naphthalene, ammonia, cyanogen, and sulphur. Owing to the necessity, in many cases, of selling domestic gas on a candle-power basis, it is not advisable to remove such valuable products as benzol and toluol from the gas works product, and, as a rule, these constituents must therefore be sought in the products from the coke oven.

The appended diagram, adapted from one prepared by W. J. Butterfield, approximates the average yield of primary products, the return of secondary products secured from the primary, as well as the ultimate yield of some of the more important subsequent products, the amounts secured being based on the distillation of 100 tons of coal in gas works practice.

While this diagram gives the total amount of coke produced as 70 tons per 100 tons of coal carbonized, the amount of coke of salable size will hardly average more than 50 tons, and often less, due to the amount used as fuel in the producers which supply the heat required for distillation, and to the amount of breeze produced by handling. In Germany this coke breeze is worked up into briquettes, but little has been done in this particular in this country, probably due to our still illimitable supply of coal, and to our negligence in the conservation of our resources.

The salable coke produced in coke ovens amounts to from 60 to 65 per cent. of the weight of coal carbonized, this latter coke being distinguishable from gas works coke in that it is better adapted for metallurgical purposes.

The amount of graphite produced in the retort is dependent upon the type of retort used, as well as on the heat of carbonization employed, also on the character of the coal distilled; this graphite has quite some commercial value.

The moment the gas is released from the coal, and when it is subjected to cooling, it begins to condense and to drop various compounds of a hydrocarbon nature, these compounds being deposited in conjunction with an aqueous solution of ammonia salts combined with dust and soot; these hydrocarbon substances, together with the dust and soot, form tar.

After the gas has been subjected to this process of cooling, or after the tar and a portion of the ammonia compounds have been removed, the gas is usually subjected to a washing process for the removal of the remaining ammonia, or the ammonia may be directly absorbed by passing the gas through a sulphuric acid bath.

The cyanogen in the gas may be removed either before or after the removal of the ammonia, the gas, in the first case, being washed with an iron solution with the consequent formation of ammonium ferrous-ferrocyanide, this being an insoluble product, while in the second case the gas is washed with a solution of hydrated lime and iron, this latter product being a soluble one; these products are generally converted into potassium ferrocyanide, commonly known as yellow prussiate of potash, or into sodium ferrocyanide. At present the removal of cyanogen from coal gas is a very profitable investment, but, besides this, its removal is of distinct advantage in operation, as the presence of cyanogen has a very deleterious effect on all steel work, and especially on gas-holder sheets.

The sulphur compounds are usually removed in the purifiers, but a portion is absorbed during the process of washing and condensing; this constituent, principally in the form of hydrogen sulphide, is usually absorbed by oxide of iron, but little lime being used for this purpose to-day. The sulphur thus absorbed is removed from the oxide of iron and converted into sulphuric acid. Unless special requirements call for the removal of carbon bisulphide it is retained in the gas, as its removal entails quite some difficulties and its economy is open to question.

The apparatus usually employed in gas works practice is so constructed as to remove not only the so-called impurities, but also valuable by-products by condensation and absorption, the removal by condensation being due to the fact that the coal is distilled at very high temperatures, thus causing the formation of various gaseous products which do not remain in the gaseous state at ordinary temperatures, and which are therefore readily removed during the process of cooling.

This short explanation of the method of operation and the statement of the nature of the by-products to be expected enables us to give a more detailed description of the products and their uses.

Coke is the first by-product obtained through the dry distillation of coal, and it is the residue left in the retort or oven chamber after the volatile products have been driven off. The composition of the coke is, of course, dependent upon the character of the coal carbonized; it is hard and brittle, and varies in color from very dark to silver gray, being composed of highly complex com-

pounds of carbon, hydrogen, oxygen, nitrogen, and sulphur. The porosity or density of coke is dependent upon the type of retort used for distilling and upon the method of quenching and handling the coke after it has been ejected from the retort; in gas works practice vertical retorts produce a coke of maximum density, due to the fact that the weight of the coke itself causes a sintering of the coke particles. Gas works coke is generally used for domestic purposes, the metallurgist depending in most cases on the product received from the coke oven.

The late Prof. Vivian B. Lewes, of England, said: "Among the factors that lead to the commercial supremacy of a country, by far the most important is the command of fuel or other source of power; and England's position in the past has been governed largely by her coal fields, which in little more than a century raised her to the forefront as a commercial power. The very abundance of our coal supplies was a source of weakness, as it led to outrageous waste, polluted our atmosphere to a criminal extent, and so encouraged uneconomical methods of using it as seriously to deplete our available stock, the result of which has been the increase in price during the last few years, and the certainty that the future will see further advances but no fall to the old rates. The day of cheap coal has gone, never to return."

If this statement is true for England, how much more so is it applicable to our own conditions, where so much remains to be done in conserving our fuel beds, and this conservation can be greatly aided by a concerted effort to educate the user in the benefits to be derived from the burning of coke; but, here again, we find that in the manufacture of metallurgical coke the warning has not been heeded, and this industry in many instances exhibits a prolific waste which is almost criminal. The change from the bee-hive to the by-product oven is very slow, but it is progressing; we find that in 1893 the bee-hive ovens produced 9,464,730 short tons of coke, the by-product ovens producing only 12,850 tons during this same period; in 1901 the product was: bee-hive ovens 20,615,983 tons, by-product ovens 1,179,900 tons; in 1910, bee-hive ovens 34,570,076 tons, by-product ovens 7,138,734 tons; and in 1913 the bee-hive oven product amounted to 33,584,830 tons, while that from the by-product ovens was 12,714,700 tons. It is true that the total consumption of coke has increased, but while that produced by the bee-hive ovens in 1893

amounted to 99.99 per cent. of the total, this was decreased to 94.59 per cent. in 1901, to 82.88 per cent. in 1910, and to 72.54 per cent. in 1913.

A series of tests made by the American Radiator Company to determine the efficiency of domestic fuels showed that gas coke of nut size led the list with an efficiency of 78.7 per cent., followed by gas coke of egg size with 75.43 per cent.; Pittsburgh coke with 71.40 per cent.; anthracite coal with 66.30 per cent., and Pocahontas coal with 66.10 per cent. It was also shown that in ease of kindling Pocahontas coal stood first, but gas coke of nut size was a close second, followed by gas coke of egg size, Pittsburgh coke, and anthracite coal last. Gas coke burns with an even, smokeless fire, it is easily controlled and clean to handle; it is also probably the most economical fuel on the market, and there is no reason why it should not displace many forms of domestic fuel now in use, thus greatly assisting in conserving our coal supply and adding benzol and toluol, with their subsequent products, to our source of national wealth.

Retort graphite is produced by the decomposition of the hydrocarbons in the gas, these latter constituents having been deposited on the walls of the retort. Owing to its poor heat-conducting qualities, it must be removed periodically from the inside of the retorts, clay retorts requiring more frequent cleaning periods than do those made of silica.

This graphite has found its most important application in the production of carbon electrodes, the raw graphite being thoroughly cleaned, crushed into a powder, and then formed into a plastic mass by the admixture of coal-tar and lamp-black; this mass is formed into rods by passing it through a hydraulic press.

The rod thus formed is then baked in a kiln, where the coal-tar is decomposed by heat, producing graphitic carbon, which combines with the retort graphite and forms a hard but brittle mass.

Tar is chiefly removed from the gas by progressive condensation, and, when removed in this manner, is accompanied by so-called gas liquor, or ammonia liquor, these two liquids being later separated by virtue of their difference in specific gravity. The gas, after this treatment, still contains a certain amount of tar in the shape of a fog or mist, and this is usually removed by friction in some sort of mechanical extractor.

These accepted methods of tar removal are now being re-

placed by others of greater value, such as the electric de-tarring system in which the gas is sent through an electric field, the action of which is to cause the tar to coalesce and drop out of the gas, and the system which embraces progressive washing combined with progressive cooling, in which, due to the fact that the gas is not cooled below the point where any volatile hydrocarbons are condensed or absorbed by the effluent, the tar is fractionated into pitch, heavy oils, and middle or light oils, without the usual interposition of a tar still.

Tar is one of the most valuable of all coal-gas residuals, and while, in this country, owing to economic conditions, it has found quite some extended use in its original form, it finds its greatest value in its application in the arts; the distillation of tar at certain temperatures produces a water-like oil, which in turn forms the base of so many of the beautiful coal-tar colors so much in demand at present. Carbolic acid, naphthalene, anthracene, and benzol are also produced by this distilling process, and each of these constituents in turn produces a long series of other products.

Naphthalene is one of the gas constituents which accounts for a great deal of the trouble experienced in present-day methods of carbonization, but its removal can be accomplished by washing the gas with a suitable oil, such as anthracene or creosote oil, or water gas tar, the resultant emulsion being gradually cooled, thus causing a separation of the naphthalene crystals.

The formation of naphthalene is probably due to the high heats employed in present-day carbonization, it being a generally-accepted fact that this formation is brought about by a partial decomposition of the tar in the gas. Fortunately, the greater portion of the naphthalene produced goes over into the tar effluent and is thus removed with the latter, as its excessive presence in the apparatus and gas mains usually causes a stoppage. Naphthalene is also due to the character of the coal used, and upon the time of contact between the gas and the hot coke and hot retort walls. Besides other domestic uses, naphthalene is of great importance at present in the production of dyes.

Cyanogen is a carbon-nitrogen compound, and it is probably produced during the period of carbonization in the form of hydrocyanic acid by the decomposition of some of the ammonia due to the contact of the gas with the hot coke and the hot retort walls, this statement being substantiated by the fact that the

quantity of cyanogen produced by the carbonization of any particular coal bears a certain relation to the amount of nitrogen (ammonia-producing agent) in the coal.

In its gaseous form cyanogen is colorless and very poisonous; in combination with potassium it forms potassium cyanide, this latter compound having found its largest application in the cyanide process of gold extraction, which process depends upon the solubility of gold in a dilute solution of potassium cyanide in the presence of air or some other oxidizing agent; this process is best adapted for use with free-milling ores after the greater portion of the gold has been removed by amalgamation, thus recovering such portions as were not taken up by the amalgam, the gold being later usually separated from the cyanide solution by an electric or metallic precipitation process.

Potassium ferrocyanide is the base of a great many cyanogen products, one of the principal products being Prussian blue; this coloring matter is obtained by mixing the potassium ferrocyanide with a solution of ferrous sulphate, a grayish-white precipitate of ferropotassic ferrocyanide resulting, the mother liquor, which contains potassium sulphate, being removed from the precipitate by decantation. After this precipitate has been allowed to settle, it is washed with a large amount of water and then oxidized, this oxidation giving it the beautiful blue color required in the dyeing industry.

In one process covering the removal of cyanogen from gas, iron sulphate, commonly known as copperas, and ammonia are used as the two reagents necessary to combine with the cyanogen, and a certain portion of the ammonia thus removed from the gas remains in the cyanide cake, the final resulting compound being ammonium ferrous-ferrocyanide. This process, therefore, requires that the cyanogen be removed before the ammonia has been extracted, but in another process the ammonia is replaced by milk of lime, and consequently follows behind the ammonia extraction process, the final product being calcium ferrocyanide.

In another process used in England the cyanogen is removed from the gas by washing the latter with a solution of soda and ferrous carbonate, the resultant liquor being deprived of its ammonia by evaporation. This liquor is then pumped through a press where the insoluble matter is removed, the cleared solution being then crystallized, giving sodium ferrocyanide, or prussiate

of soda. This latter product is washed for purification and then recrystallized.

Ammonia is a nitrogen-hydrogen compound, and, besides being a source of great revenue to the coal-gas producer, its removal from the gas is necessary for both practical and hygienic reasons; its presence in the gas exercises a destructive influence on the brass and copper work of meters and gas fittings, and when burned in conjunction with gas it gives off noxious fumes of oxides of nitrogen.

The usual method employed for the removal of ammonia depends upon the solubility of ammonia in water, as at ordinary temperatures water can absorb about 708 times its volume of ammonia gas. Raw ammonia liquor from a gas works usually contains from one to two per cent. of ammonia, and, owing to the excessive cost of transporting this weak liquor, it is usually worked up into concentrated liquor, aqua ammonia, or ammonium sulphate.

Concentrated ammonia is a product obtained by distillation of the raw liquor with lime, and absorption, in water, of the ammonia evolved. It is used in the production of other ammonia compounds.

Aqua ammonia is a solution of ammonia in distilled water, a great deal of it, in a dilute solution, being used for cleansing purposes.

Ammonium sulphate is produced by distilling the liquor and absorbing the ammonia vapors in a sulphuric acid bath, thus forming the sulphate crystals; or it may be made by passing the gas, after the tar has been removed, directly through the acid bath, this being the so-called direct process. The only really direct process, however, is the one in which the ammonia in the gas is combined directly with the sulphur radical, the latter also existing in the gas, this compound being later oxidized. This process requires that the gas be washed with ammonium polythionate, the latter absorbing both ammonia and hydrogen sulphide, the resultant liquor being oxidized or regenerated by means of sulphur dioxide gas, and after the liquor contains about 35 to 40 per cent. of ammonium sulphate in solution it is boiled, resulting in the breaking down of the polythionates with the consequent precipitation of the sulphur; this sulphur is returned to the sulphur stoves for the further production of sulphur dioxide, while the cleared liquor is evaporated to crystallization, this

method of procedure therefore requiring no sulphuric acid for the production of the salts, but finding all of the necessary reagents in the gas itself. Sulphate finds its greatest use in the manufacture of fertilizer, it being the active nitrogen-carrying agent in this product; it is also used for the production of other ammonia compounds.

Ammonium chloride, commonly termed sal ammoniac, is produced by using hydrochloric acid as an absorbing agent, followed by evaporation and crystallization. Ammonium sulphate is the principal source of sal ammoniac production in this country, the sulphate being heated in conjunction with common salt for its formation. Sal ammoniac is used as an agent in the galvanizing process, for soldering, and as an agent in electric batteries.

Liquid anhydrous ammonia is produced by freeing the ammonia gas of all moisture and impurities, after which it is liquefied under pressure; this product is used in the production of low temperatures by the absorption of heat, as in refrigeration.

Ammonium carbonate is produced by heating ammonium sulphate in conjunction with calcium carbonate, and it finds its greatest application in the scouring of wool.

Ammonium nitrate is produced by neutralizing nitric acid with ammonia, and it is used in the manufacture of explosives.

There are many other ammonia compounds, but the ones here cited are the principal products, and they can all be prepared from ammonium sulphate, thus making this latter compound one of the principal by-products of coal distillation.

Benzol and its homologues are obtained during the process of tar distillation and from the products due to coke oven distillation, they being secured in the latter case by washing the gas with a suitable oil, the resultant product being purified by repeated distillation and washing, thus separating it into benzol, toluol, xylol, and solvent naphtha; the greatest usefulness of these products is in the production of dyes, explosives, artificial perfumes, and pharmaceutic compounds.

COAL-TAR AND BENZOL PRODUCTS.

A large number of our industries are dependent upon the use of coal-gas by-products for their successful operation, as is witnessed by the following statement, taken from the census of 1909. The

principal industries dependent upon coal-tar products, with the number of employees, capital invested, and annual value of product, are:

Industry	Employees	Capital	Product
Textile	916,000	$1,841,000,000	$1,685,000,000
Leather	62,000	323,000,000	328,000,000
Paper	81,000	400,000,000	260,000,000
Paints and colors	30,000	250,000,000	

Thus we find a total of 1,089,000 persons employed in these four industries, with a capital investment of $2,814,000,000, and an annual product for the first three representing $2,273,000,000 in value. Since the 1909 census these industries have all increased their production, and, when taken in conjunction with other manufacturers, such as the producers of shoe dressings, writing and printing inks, etc., it is perhaps safe to estimate that at present fully 2,000,000 persons find employment in industries which are dependent upon dyestuffs for their success.

Artificial dyestuffs, produced from the by-products of coal distillation, have practically displaced those formerly used, such as natural indigo, cochineal, fustic, madder, and many others, and this is properly so, because the artificial material is easier applied, has a greater brilliancy of color, and can be secured in a great variety of shades; but, unfortunately, our American industries have always depended on Europe to supply the necessary material. Statistics teach us that 80 per cent. of our coal-tar dye requirements are imported from Europe, principally from Germany, the other 20 per cent. being produced by American manufacturers; but here again we find that we must turn to Europe for our supply of the greater portion of the necessary intermediates, or raw product, before we can produce this 20 per cent. of coloring matter.

The present war soon brought about an acute situation among our manufacturers, as the stock on hand was soon depleted, and a replenishment became almost impossible. The seriousness of this situation can readily be recognized when I mention that "sulphur black" increased in price from 20 cents to as much as $3 per pound; indigo from 15 cents to $1 per pound; paranitraline from 15 cents to $1.75; aniline oil from 10 cents to $1.75; betanaphthol from 12 cents to $1.50; and so on through the list. As regards the raw or primary material, I might mention that the

price of benzol has increased from 20 cents to as much as $1.20 per gallon, with about 70 cents as a contract price, while toluol has increased from 25 cents to about $6 per gallon, with a contract price of about $4.25.

These conditions certainly compel us to turn seriously towards our own supply of tar and benzol and cause us to question ourselves as to our ability to do that which we have permitted others to do for us. Several American manufacturers have gone ahead vigorously in an attempt to supply our domestic needs, and credit for stepping into this breach must be accorded such firms as the Shoellkopf Aniline and Chemical Works, Inc., Buffalo, N. Y.; The Hudson River Aniline Color Works, Albany, N. Y.; W. Beckers Aniline and Chemical Works, Brooklyn, N. Y.; Central Dyestuff and Chemical Company, Newark, N. J.; and Heller and Merz Company, Newark, N. J.

Other concerns have taken up the manufacture of intermediate products from our raw material, and, while all of these manufacturers are being supported by the allied industries today, the question as to their future is still an open one, and reference to this will be made later.

We have the necessary raw material, tar and benzol, on hand, and a lack of these products will soon bring about their further recovery if the situation should demand it, as the greater amount of coal carbonized for the production of coke in America, as previously stated, is still produced in the wasteful bee-hive oven. Economic and commercial conditions have prevented the development of the dye and other allied industries in this country, and consequently our manufacturers have in the past diverted their raw material in great measure into the production of tar oils and pitches.

Tar is a very complex substance, and it has been estimated that it consists of a mixture in excess of two hundred chemical compounds. The constituents of tar are usually divided into three classes, the first being the hydrocarbons, the second the phenols, and the third the nitrogenous compounds, these classifications being made in accordance with the chemical reactions of the compound in question. The hydrocarbons, as can be seen from the name, are composed of hydrogen and carbon, and they are termed chemically indifferent substances because they exhibit neither alkaline nor acid properties. The hydrocarbon

compounds, of which benzene, toluene, xylene, naphthalene, and anthracene are the most valuable, form the principal portion of coal-tar. The phenols, or the second class of constituents, consist of oxygenated bodies of carbon, hydrogen, and oxygen, being known as the "tar acids." Owing to their weakly acid condition, they can be dissolved in caustic alkali solutions, but not in dilute acids. The most important members of the phenol group are carbolic acid and cresol. In the third class we find compounds composed of carbon, hydrogen, and nitrogen, these compounds being of a basic nature and soluble in acids.

The distillation of coal-tar thus serves to produce a number of fractions, and these fractions in turn form the base for manufacturing various other important products. Distillation of the average coal-tar usually gives us four fractions, the first being "light oil," which comes over at a temperature of between 70° and 160° C. (158° and 320° F.); the second is a "middle" or "dead oil," coming over between 160° and 230° C. (320° and 446° F.); the third is a "heavy oil," including anthracene oil, and it comes over at between 230° and 360° C. (446° and 680° F.), while the fourth is pitch, or the residue above 360° C.

The first fraction, or "light oil," produces such intermediate products as benzene, toluene, xylene, and phenol (carbolic acid), while the crude commercial products are benzol and solvent naphtha; the intermediate chemical products are nitrobenzene, aniline salts and oils, and carbolic acid, while the refined chemical products are the nitrotoluenes, diphenylamine, dyes, hydroquinone, and various medicines and drugs.

The "middle oil" gives us phenol, cresols, naphthalene, and heavy hydrocarbons as an intermediate product, the crude commercial products being creosote oil, lamp-black, and various disinfectants. The intermediate chemical products are carbolic acid, picric acid, phthalic acid, naphthols, naphthylamine, and salicylic acid, while the refined chemical products consist of picric acid, the picrates, and several other nitro-compounds used in the manufacture of explosives; naphthol dyes, colors, indigo, and refined carbolic acid.

The "heavy oils" produce cresols, naphthalene, anthracene, heavy hydrocarbons, and quinoline bases; the crude commercial products consist of oils used in road making, lamp-black, creosote oil, roofing and paving tars. The intermediate chemical prod-

ucts consist of anthraquinone and alizarin, while the alizarin dyes are known as the refined chemical products.

The fourth fraction consists of soft and hard pitch, a large portion of which is used in the manufacture of protective paints.

The manufacture of aniline dyes necessitates quite a number of very complicated chemical combinations, and the chief sources of this product are to be found in benzene, toluene, and phenol, or in the nitro-substitution products of these compounds; this material is used in conjunction with nitric, sulphuric, and acetic acids, alcohol, sodium nitrite, caustic alkalies, zinc dust, bromine, and chlorine.

The naphthol dyes are produced from phthalic acid, the naphthols and naphthylamines, etc., these being intermediate products derived from naphthalene. The eosin dyes are due to benzene and naphthalene through the medium of resorcin and phthalic acid; indigo is also a naphthalene product.

Anthracene is converted into anthraquinone by oxidation, and this in turn gives us the hydroxyanthraquinones and such derivatives as the alizarins, purpurin, etc., all of which are used in the production of alizarin dyes.

Carbolic acid, or pure phenol, is, as stated before, obtained from both the light and middle oils, and it can also be made synthetically from benzene; it is used as a drug as well as an antiseptic, and it occupies a very important rôle in the manufacture of picric acid and some of the dyes.

The manufacture of synthetic phenol, using benzol as a base, was not encouraged or practised in this country before the present war, and consequently little attention has been paid to this branch of conservation, and it may therefore be interesting to give a short explanation of its manufacture.

The benzol stripped from the gas, or secured as a distillation product from tar, is first sulphonated by mixing about 2.7 parts of 98 per cent. sulphuric acid with one part of benzol in a cast-iron vessel having a capacity of approximately 400 gallons, this vessel being supplied with means for both heating and cooling the liquid, the escaping matter passing through a reflux cooler, about 150 pounds of benzol being treated at a time. This mixing vessel is provided with an agitating device, and the agitator is set in motion as soon as the benzol is admitted, the sulphuric acid being in the mixer before the benzol is added.

As soon as these two liquids mix, the temperature rises to between 62° and 68° C. (144° and 154° F.), and when the chemical reaction produces no further increase, external heat is applied to a point corresponding to the boiling-point of benzol, about 88° C., or 190° F. This sulphonating process is usually completed in from seven to eight hours.

The sulphonic acid produced as per the above is run into a neutralizing vessel, the latter having a lead lining, where it is first neutralized with milk of lime, and then treated with waste calcium carbonate; this treatment is liable to thicken the liquor, and, if so, some water is added to thin it out, after which the mixture is subjected to a boiling temperature for about one-half hour, steam being used for this purpose. After the steam has been turned off, a volume of water amounting to 150 per cent. of the volume of the original sulphonation mixture is added, this being necessary in order to prepare the calcium sulphate for washing and filtration.

This mixture is now forced through a filter press, where it is also washed with water, the latter amounting to about 50 per cent. of the volume of the mixture. The resultant product is a calcium benzene-sulphonate mixture, and this is now treated with solid sodium carbonate in order that it may be converted into a sodium salt, while the precipitated calcium carbonate is used in neutralizing the sulphonation mixture. The sodium benzene-sulphonate solution is now evaporated, the resultant salt being dried and pulverized, this dried product being placed in a fusion vessel where about 500 pounds of caustic soda are melted with about 50 pounds of water for every 600 pounds of the dry sodium benzene sulphonate, the caustic soda and water being heated to about 270° C. (518° F.) before the sodium benzene-sulphonate is added; heating is continued up to about 315° C. (600° F.), a still further, but slight, rise in temperature taking place after the heat is turned off, the operation being considered complete when all of the sodium salt has been dissolved and the mixture is thin.

The resultant product is now removed from the fusion vessel by means of ladles and placed on shallow trays, where it is allowed to cool, after which it is crushed and dissolved in water, being then treated with sulphuric acid until sulphurous acid begins to go off, this sulphurous acid being finally blown out of the vessel with an air blast, thus separating the crude phenol from the mix-

ture, the latter being then distilled, and the phenol crystals recovered by crystallization. The phenol crystals obtained in this manner usually contain some sulphur compounds which produce disagreeable odors, but this can be removed by distilling the crude product in conjunction with animal charcoal.

The light oil fraction is also responsible for the production of photographic developers as well as of such drugs as phenacetin, acetanilide, antipyrine, aspirin, saccharine, and phenolphthalein.

The synthetic production of many perfumes also owes its existence to coal-gas tar, and it is almost impossible for the layman to differentiate between the natural products and the synthetic substitutes.

Modern coal-tar dye classification divides this product into eight classes, or

1. Acid dyes;
2. Tannin dyes;
3. Dye salts;
4. Sulphur dyes;
5. Vat dyes;
6. Mordant dyes;
7. Developing dyes;
8. Albumin dyes;

and they may be described as follows:

1. The greater portion of the acid dyes consist of sodium salts of sulphonic acids or organic acids or nitro acids, and they are represented by the azo dyes, the eosines, and picric acid. They are used principally for dyeing wool and silk, this material being dyed directly with the aid of an acid or an acid salt in the bath. Cotton is not dyed by these compounds.

2. The tannin dyes are also classed as basic dyes, consisting in large part of hydrochloric acid salts of color bases; if cotton is first treated with tannin we find that it is easily dyed, but we find that wool and silk can be dyed directly without the aid of this intermediate treatment.

3. The dye salts receive their names from the neutral or alkaline salts which are dissolved in the dye solution; they are also termed direct-cotton dyes and substantive cotton dyes, consisting usually of sodium salts of sulphonic or organic acids, the cotton fibre taking them up in this state. The dye-bath also receives some common salt or Glauber's salt.

4. The sulphur dyes consist of a class of colors which are very popular owing to their cheapness and fast qualities. The bath is made alkaline with the soluble sulphides, the color being later developed by oxidation after the cotton material has been removed from the bath.

5. The vat dyes show but little attraction for the common fibres, and they are fixed on the material by reducing them to their leuco compounds in the vat. The material to be dyed is immersed in this reduced dye and thus becomes saturated with it, after which it is exposed to the air, where the color is developed by oxidation.

6. The mordant dyes are of a weak acid character. In order to cause their retention by the fibre, they must be converted into color lakes by means of a mordant, with which the fabric is impregnated prior to treatment in the dye bath. The color known as Turkey red is an example of this class of dye, being made from alizarin, which is yellow and is almost insoluble; the cotton fabric to be dyed is first treated with aluminum salts and Turkey red oil, then is boiled in the alizarin, after which it is treated with calcium salt, the Turkey red color resulting.

7. The developing dyes, owing to their insolubility, cannot be applied directly to the fabric to be dyed, but they are produced upon the fabric itself by first saturating the latter with one soluble component and then immersing it in a second bath of another soluble component, these two components uniting and forming an insoluble dyestuff.

8. The albumin dyes will not adhere of themselves, and they require that the fabric be first treated with some strongly adhesive substance, the principal substance used for this purpose being albumin.

This classification of dyes is only mentioned in order to make somewhat clearer the complex nature of the dyer's art.

The coal-tar dyestuffs found their origin in England, where, in 1856, W. H. Perkin discovered mauve, a sort of violet: this was an accidental discovery, as Perkin was seeking something entirely different, but his chemical ability, combined with a keen business sense, caused him to persevere in this line of chemical research, and he lived long enough to find his crude beginning develop into an immense business which utilized a material, coal-tar, that had previously been considered worthless. The discovery of mauve was soon followed by magenta and fuchsin, while the

soluble blues were discovered in 1862, Hofmann's violet and Bismarck brown in 1863, naphthol or Martius yellow in 1864, and the nigrosines in 1867.

These beginnings soon drew the attention of the Germans to this new industry, and, recognizing the immense possibilities in its development, they very quickly applied their usual patient perseverance and intelligent research to the advancement of this new art; this resulted in the production of orange, red, malachite green, chrysodine, scarlet, metanil yellow, methylene blue, and the eosines between 1875 and 1878; auramine was first produced in 1883; tartarzine and benzopurpurine in 1884; Congo red, benzoazurine, and naphthol black in 1885; diamine red in 1886, and rhodamine in 1887. The early nineties saw the discovery of direct black for dyeing cotton, and acid and chrome black for dyeing wool. It was von Bayer who first succeeded in producing indigo, but many years of patient labor were required before a practical synthetic process permitted of placing this important dyestuff on the market in a commercial sense.

From the latest reports, I learn that the Dow Chemical Company, of Midland, Mich., is erecting, or has erected, a plant for the production of 5000 pounds of 20 per cent. indigo paste per day.

Realizing that industrial progress in this line meant commercial supremacy, the Germans quickly learned that success meant patient scientific research, combined with an adequate supply of raw material, with the result that by-product coke ovens were soon established in the immediate vicinity of their blast furnaces, where the distillation of the coal for the production of the necessary metallurgical coke soon supplied them with all of the by-products required in the development of this new art, an example which we might have followed in the past with great profit, and with relief of mind at present.

The cost of producing dyes in this country is said to be 44 per cent. greater than in Germany, as it is estimated that the cost of a plant capable of producing 3,000,000 pounds of dyestuffs per year would be $104,000 in the United States and $70,000 in Germany, while the labor required would amount to $116,236 in the United States and $61,493 in Germany. The cost of material would be $443,000 in the United States and $317,000 in Germany. These comparative figures show a vast difference in favor of Germany, and the successful establishment of this industry in our

country would require that protection in some form be given the American manufacturer in order to make up this discrepancy.

The discrepancy is even greater than these figures would seem to indicate, because the German manufacturer has been in the habit of selling us his surplus production, and that at a figure lower than the one paid by the domestic consumer. The establishment of this industry in the United States means opposition to the preëminent position of the Germans, whose success is based on a solid foundation of 30 years' standing, and which, therefore, becomes a standing challenge to our chemists and capitalists. We have the necessary raw material, and we possess constructive engineering ability of a character which can supply all of the needful apparatus, but, with all this, an almost unlimited capital and patience will be required.

But this is not all that is required, as chemists, trained in this particular work, are not numerous in this country, and their necessity is shown when it is mentioned that in one German works, producing about 500 colors, we find 300 chemists employed; of these about 100 are engaged in analytical work, and the other 200 are in charge of the actual manufacture of the dyes, thus placing the production of only two or three colors under any one chemist.

After the capital has been supplied, and this new industry has been properly started, it will be necessary to secure proper legislation prohibiting "dumping" on our shores, a performance heretofore practised by the Germans, as well as a prohibition against an unfair restraint of our trade due to the arbitrary action of the German monopoly which is now allowed by foreign law, but not permitted by our own. Any scheme entered into must therefore necessarily depend upon an effective law which will prevent the control of our markets by foreign monopolies in the same manner as a domestic monopoly is now prohibited.

Advices received from Germany indicate that the German monopoly will re-enter the American market as soon as the war is over, and that it will make tremendous efforts to regain this lost business, being prepared to make extraordinary concessions in order to take the business from its infant competitors. It therefore is required of us that we place this new industry on a firm foundation as soon as possible, and that we seek such Federal legislation as will permit the continuance of the project without financial loss.

The dyestuffs subject could be treated at greater length, but the explosives, due to coal-gas residuals, also claim some little attention. The picric acid produced from carbolic acid, or phenol, is the base of "lyddite," used by Great Britain; of "melinite," used by France, and of "shimose" powder, used by Japan; but toluene, a tar or benzol product, is responsible for the production of the new explosive, "trinitrotoluene," commonly known as "T. N. T.," so much used in the present war.

Both picric acid and "T. N. T." are manufactured by a sulphonating and nitrating process, the method of operation in both cases being somewhat similar in detail. Phenol is produced by permitting that fraction of tar distillation coming over at a temperature between 150° and 230° C. (302° and 446° F.) to stand and cool until the naphthalene crystallizes out, after which the mother liquor is agitated in the presence of a solution of caustic soda, the latter combining with the phenol and forming sodium phenolate. This sodium phenolate, due to its weight, sinks to the bottom of the mixing chamber, whence it is drawn off and treated with sulphuric acid, this latter treatment setting free the phenol. This compound is now run into a still and fractionated, the phenol coming over at a temperature between 180° and 190° C. (356° and 374° F.) and crystallizing in sharp, needle-like crystals from the distillate. An equivalent weight of concentrated sulphuric acid is now mixed with the phenol, and the mixture is heated in an iron vessel by means of a steam coil to a temperature of slightly above 100° C. (212° F.). The mixture is next allowed to cool slowly, after which it is dissolved in twice its weight of water, and then slowly added to three times its weight of nitric acid, the nitration being completed by heating with steam after all fuming has ceased. This final mixture is now allowed to slowly cool down, thus permitting the picric acid to crystallize out, after which it is purified by washing with warm water, and then recrystallized.

This explosive, due to its acid nature, combines with metals, and thereby forms picrates, the latter in some instances being much more sensitive to percussion and friction than picric acid itself; this is a serious drawback, as it renders the shell containing this compound subject to explosion while in storage or during transportation, by heavy jolting. This, as well as many other disadvantages, caused the explosives manufacturers to turn their attention to another source, and they finally evolved the present-

day trinitrotoluene. This compound is made by first converting the toluene into a mononitro compound, after which it is treated with nitric acid at a slight increase in temperature, thus converting the mononitro compound into dinitrotoluene, after which the latter is nitrated in a sulphuric acid solution with concentrated nitric acid, the final product thus formed being trinitrotoluene. This compound is also produced from orthonitrotoluene by means of a sulphonating process similar to that used in the production of picric acid, after which it is nitrated and the resultant crystals are then purified in alcohol, being recrystallized and the alcohol removed in a centrifugal hydro-extractor.

In these statements I have tried to explain to you the wonderful properties possessed by a by-product which some years ago was considered a waste, and I trust my words will assist in calling your lasting attention to the possibilities of creating and maintaining an industry which can only redound to our credit and which will certainly add to our national wealth by not only conserving a vast amount of fuel, but which will also retain in our country a large sum of money which is annually expended in the purchase of materials which should be manufactured in the United States.

The True Nature of Speech with Application to a Voice-operated Phonographic Alphabet Writing Machine. J. B. FLOWERS. (*Proceedings of the American Institute of Electrical Engineers,* February 9, 1916.)—That speech is a rapid variation in intensity of the voice and mouth-tone according to definite sound patterns, called letters of the alphabet, is proved by showing that speech is the result of action of the mouth-parts in varying the intensity of the voice and mouth-tones and through photographs taken with the string-galvanometer of each letter sound of the alphabet, showing definitely the characteristic variation in intensity of each tone for each letter of the alphabet. From the curves the phonographic alphabet is obtained by measuring the variations in intensity of the main tone of the record.

A design for a voice-operated phonographic alphabet writing machine is described. The object of this device is to record speech automatically in ink on paper in the form of an easily-read, compact system of natural characters called the phonographic alphabet. Its design comprises a high-power telephone transmitter controlling electric resonator circuits, the intensity of currents in which is measured by the vibration of mirrors reflecting light upon a selenium cell connected to a special recording pen.

PRODUCTION OF LIGHT BY ANIMALS.*

BY

ULRIC DAHLGREN,

Professor of Biology, Princeton University.

LIGHT PRODUCTION IN CEPHALOPODS.

This wonderful group of animals is counted as constituting the highest and best organized of the five classes of mollusks. As is well known, it is divided into the earlier group of Tetrabranchiata which lived in past ages and of which but one genus with four species is left in the living state, and the Dibranchiata or squids and octopi, which are of more recent origin, possibly from tetrabranchiate origin, and whose members are found in all the seas of our globe. Some 4200 species of extinct tetrabranchiate cephalopods have been described, while of the living dibranchiates we know of over 450 species.

We know but little concerning the tissue specializations of the tetrabranchiates, and in the living form of this order, the genus *Nautilus*, we find no luminous organs. It may well be possible—in fact, it is probable—that the extinct order did have numerous species that could produce light, although we are, so far, barred from any knowledge of this fact because of their fossil state, in which only the hard parts have been preserved. On the other hand, some of the most powerful light organs, under complete nervous control and supplied with the most perfect lens, reflectors, and other accessory parts, are found in the numerous species of the dibranchiates. We must except from this generalization, however, one branch of the Dibranchiata, the octopoda, whose members are almost entirely devoid of luminous organs. In a few cases such organs have been reported, but no sufficiently reliable report or descriptions are as yet forthcoming.

In spite of the large number of luminous squids and of the many descriptions of their various light organs we still lack exact and careful experimental work on any one form. Some very good observations have been made on the color of the light even of some deep-sea forms from as far down as a mile in depth, but

* Continued from page 400, March issue.

such work lacks good scientific research with the spectroscope and chemical experimentation. And in some of the reports of the great deep-sea expeditions of Germany, England, and France we find fairly good reports on the general appearance of the luminous organs of a number of squids, together with an account of their morphological distribution and good descriptions of their histological structure.

A number of generalizations can be made, at this point, as to the larger features of the light organs of these animals. The light organs are widely different in their method of operation, and we find two main types in this regard. First, we may consider those that have an internal combustion in which the secretion never leaves the cells that produce it. In the second place, we see other species of squids that possess a gland that ejects its secretion into the surrounding water, where the luciferine is brought into contact with the oxygen and the light is generated. This latter form is, perhaps, morphologically and physiologically, the more primitive.

Again, another general condition appears to be that almost all the light organs are found to be placed upon the ventral surfaces of the creature. And by ventral is meant the actual "under" side rather than the "morphologically ventral" surface. A partial or possible exception to this is found in the light organs that appear frequently on the arms in several forms. This condition has led to the inference that the animals might use their organs to illuminate the bottom of the sea over which they swim or some other object that is below them.

In the writer's opinion, however, the primitive purpose of these organs is the same as that of the chromatophores, to determine the color of the body. It is a well-known and accepted fact that most sea-living organisms of any size show a darker color on their upper surface and a lighter color, often a pure white, on their lower (ventral) surface. The darker colors are obtained by absorption of some light rays and the reflection of the remainder; the white by the reflection of all, or nearly all, the rays. In such a case the "white" result is obtained not by reflecting all the rays (which are few and weak in the sea depths), but by generating new rays in these photophores, which thereby become a sort of chromatophores.

In further confirmation of this idea, the writer calls attention

to the fact that the light from many squids has been reported to be of a decided bluish color. Thus any animal situated below such a squid and looking upward at it from below would see a bluish light that would blend with the sunlight, that reaches a depth up to as much as 100 fathoms in the daytime. And, as many of these creatures live in less than that depth or migrate at certain periods into less than 100 fathoms, as described for *Watasenia* by Sasaki, it seems that this condition of a mildly illuminated under surface would be of value to them.

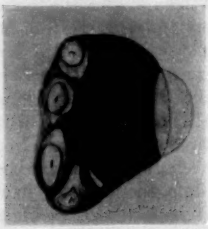
While this theory would seem to apply best to those squids possessing a large number of lights distributed all over the ventral or lower surface, it could also be applied to those having a fewer number of larger lights: up to a certain point where their lights become very large and few and placed in unusual positions, and especially where they show as many as three distinct colors, some other unknown factors and uses must be explained, and no adequate explanation has been forthcoming. It is possible that in this case they are used as a mating adaptation.

The greatest number, by far, of the squid light organs appear to be, at first sight, of mesodermal origin; *i.e.*, the light-cells are deep under the outer layers of the skin. Even the lens tissues, and certainly the reflector cells, appear to have come from mesodermal tissues. No careful ontogenetic studies have made it possible to determine what the real facts are, owing to the difficulties of getting the proper embryonic and larval stages, but when we carefully study the few forms that possess an organ whose secretion is thrown out of the cell into the surrounding water, and make certain comparisons of these organs with the numerous organs whose secretion is consumed by the light processes inside of the cell body, we can see the strong probability that all of these organs have passed through a long phylogenetic development from earlier forms in which all the organs were derived from strictly ectodermal tissues. The writer feels sure that when we are able to secure and study the embryos of these rare animals we will find that all parts of the light organ, with the exception of the reflector layers, have an ontogenetic origin in the embryonic epithelium, and he bases this idea on the conditions found in the family Cranchidæ and in *Sepietta media* and *Heteroteuthis impar*. The reasons for this belief can perhaps be made plain most easily by a study of some of these forms.

The family of Cranchids are small, usually compact squids found in very deep water. They are pelagic in habit, swimming in these great depths of hundreds of fathoms, yet not living on or near the bottom. But few have been captured by the dredge or vertical tow-net, and yet some twelve or fifteen kinds have been described. The most interesting and valuable work on the subject is that by Dr. Carl Chun in volume eighteen of the scientific reports on the German deep-sea expedition on the steamer *Valdivia*.

Several light organs are found on some of the genera and species of this family. Their most frequent development is on the ventral surface of the eye. But, besides these, two large, symmetrically-placed light organs also appear on the visceral mass

FIG. 1.



Ventral view of the eye of *Liocranchia valdiviæ*, dissected out from the head. The four luminous organs are plainly seen, each with a slit-like opening into its interior. (After Chun.)

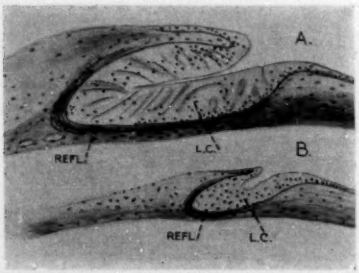
on several of the genera or species, particularly on the genus *Corynomina*.

Our interest centres on the eye organs of *Cranchia*, *Liocranchia*, and *Leachia*, because here we find a primitive condition which may, and probably does, represent an ontogenetic condition in most of the light organs of other squids. Fig. 1 shows a view of the under surface of the eye of *Liocranchia valdiviæ*, on which one may easily see four slightly protruding organs, each of which shows a slit-like entrance into its inner part. These are the ocular light organs. In the genus *Cranchia* there are thirteen such organs, while in other genera of the family they may be reduced to two in number or entirely absent. This under surface of the eye is covered by the projecting flap of tissue of the under surface

of the head, but this is a reflected flap, and thus these light organs are on a morphologically outer surface, and their slit-like opening communicates with the watery medium in which the animal lives.

When a section is taken through such an organ, perpendicular to the surface of the eye and at right angles to the line of the slit opening, we find a view as shown in Fig. 2, A and B. Here is seen a gland which is composed of what is practically simple epithelium, a continuation of the simple epithelium that covers the surface of the body in all mollusks, the squids included, but which is a comparatively thin and delicate layer in the squids. The transition of this

FIG. 2.



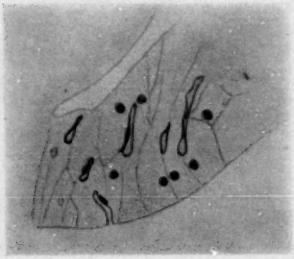
Vertical sections of two of the ocular light organs of the cranchid squid *Cranchia scabra*. B is a slightly more primitive form than A. *refl.*, reflector; *l. c.*, light-cells. (After Chun.)

body epithelium into the glandular epithelium (*l. c.*) of the light organ is shown in both A and B of this figure.

The gland consists of a single infolding of the surface lined by these glandular cells, which still maintain their perfect alignment and whose proximal ends rest on the connective tissue below, while the distal ends form a single line continuous with the outer body surface. Individually the cells are thick and glandular in structure and some of them show a denser condition of their cytoplasm than others, as A in Fig. 2 will show. Undoubtedly the luciferine is secreted in these cells. The light generated by these organs has never been studied, because the animals are rare and are usually dead or much exhausted when brought up from the great depths in the trawl or vertical net.

The question naturally arises: Is the light actually produced in the cytoplasm of the cells, or is the luciferine discharged from the cells into the lumen of the gland, there to meet the oxygen and enzyme and fulfil its function of light production? Several indications are present to show that the first method prevails in this case. First, the cells appear to be of a uniform texture rather than to have a proximal distal differentiation that would indicate the reception of food materials from the blood at the proximal surface and a discharge of the finished luciferine at the distal surface. This condition is further shown by the absence of any secretion whatever in the lumen of the gland as figured by Chun.

FIG. 3.

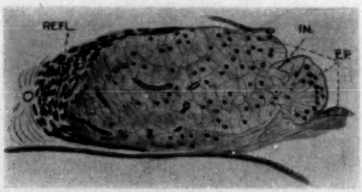


A few light-cells from Fig. 2A. More highly magnified. The nuclei and outlines of the light-cells are visible; also the capillaries, with their walls and elongate nuclei. (After Chun.)

Secondly, we find the somewhat unusual condition of blood capillaries entering the epithelium and passing between its cells to form a rich plexus at about the middle level. Were these cells to be secreting from the distal surface and securing their food material from the proximal it is unlikely that such capillaries would thus come up out of the mesoderm on which the epithelium lies. And their presence in a so far distal position in the epithelium would seem to indicate that they were as much there to carry off waste material, products of the combustion, as to furnish supplies for the secretory processes. Fig. 3 represents a portion of the epithelium from the fundus of one of these glands and shows the epithelial nature of the cells, as well as the presence of the blood capillaries and the tissues and nuclei of their walls.

All of these more primitive eye light organs show the presence of a reflector developed from certain connective tissues lying just below and in contact with the epithelial tissue (see Fig. 2, *refl.*). The cells of this structure are flat plates in form, and, since our sections cut them always at right angles to these surfaces, we find them to appear as strands containing nuclei in any such section. What the reflecting agent may be in these organs has never been worked out. In life it reflects daylight as a beautiful shimmering yellow. In the prepared sections the reflecting power appears lost. It seems not to be guanin as found in fishes and requires further study.

FIG. 4.



Section of an ocular organ of *Leachia eschscholtzii* to show a case in which the original invagination of epithelium has solidified and the lumen become almost obliterated. *ep.*, epithelial layer from which the organ was derived; *in.*, last trace of the closed lumen; *refl.*, reflector. (After Chun.)

As a next physiologically phylogenetic step in the development of the cephalopod light organ let us study one of the eye organs found in the allied cranchid squid *Leachia eschscholtzii*, and pictured in vertical section in Fig. 4, after Chun. Here it can be noticed at once that we have an organ directly comparable in many ways to the two we have just been studying. The photogenic cells of the structure are evidently an invagination and thickening of the outer body epithelium, as is testified by their plainly-seen continuity with this epithelium (*ep.*, Fig. 4). The point of invagination is represented by the depressed notch at *in.*, Fig. 4. An important change has crept into the structure of this organ, however. The photogenic cells in the fundus have abandoned their columnar and simple character and have divided and multiplied into a mass that fills the gland space and reduces the lumen to a theoretical space in the neighborhood of the former entrance to the gland. The lips of the opening remain and still

show their simple columnar epithelium as continuous with the ectoderm, although even part of this epithelium rests on the mass of light-cells instead of on the mesodermal connective tissue from which they have become separated by the intrusion of the swelling mass of light-cells below them.

The capillaries, which had already begun to grow out from their normal mesodermal field into the epithelium in the first organs described, here maintain this condition, except that, since the mass of epithelial cells in the gland was much larger and more compact, the capillary net-work is more like that found in an internal mesodermal structure. The walls of the capillaries show cells that are of a specific nature, thin walled and dense, and staining much darker than the surrounding photogenic cells. They evidently have been derived from the real mesodermal cells of the blood vascular system, and not by the transformation of the surrounding light-cells at the time that these circulatory channels are formed.

In this organ, too, as Fig. 4, *refl.*, will show, a well-developed reflector is present. It is evidently a modification of connective-tissue cells at this point, and should be studied further to see what the chemical and structural nature of the reflecting medium is and how the organ is developed. The structure of this organ confirms us in the idea previously expressed that in all these cranchid organs, no matter how epithelial in character and glandular in formation, the luciferine is not discharged into the water, but is oxidized *in situ*. Whether the exposed position of the secretory cells in the simpler forms of the organs is utilized for the absorption of oxygen or for the discharge of the products of combustion is not known.

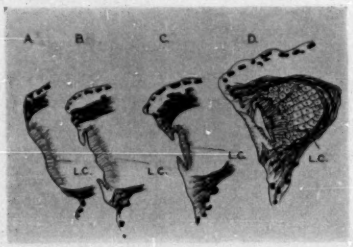
Before going further with the whole subject of squid light organs we must here consider a division that takes place in the phylogenetic series, so that, beginning with the open epithelial forms of organs just discussed, we find two types of organs. There are: first, a series of organs in which intracellular method of physiological lighting is continued and the phylogenetic cells are drawn deeper into the body, while various lens structures and corneal structures are developed over them, thus shutting them away from the external medium; and, second, a smaller series of organs in which the photogenic cells retain their simple epithelial arrangement on more or less deeply invaginated surfaces and

change the method of intracellular lighting to a method of external secretion and extracellular lighting that may be performed in morphological cavities or only upon extrusion from these cavities and contact with the water medium surrounding the living animal.

We will proceed with studies of the first-mentioned internal or invaginated forms, following the structures out in a series of typical squids to their highest specializations of light-cells and accessory structures, and then take up the second series of external secretion forms, which are far less common than the former kind.

Our next logical step in this study is to find some organ that will show us in its adult form how the photogenic cells have be-

FIG 5.



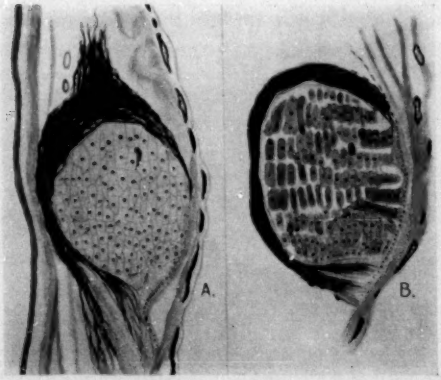
Sketches from four sections taken from an ocular organ of the cranchid squid *Leachia cyclura*. A in middle of organ. B, C, and D, sections taken at intervals toward posterior edge of organ where mesodermal elements begin to form flaps that will cover the epithelial light-cells, *i. c.* In D this covering is complete. (Modified after Joubin.)

come covered over by other tissues. Joubin has described such a formation from the cranchid squid *Leachia cyclura*. It is one of the organs found on the ventral surface of the eye, and is designated by him as being of "form D." Fig. 5 shows a series of five sections through this structure, the first one (A) being approximately at the middle of the organ, where the epithelial origin and position of the photogenic cells is quite apparent and their pseudo-stratification is indicated. In three other similarly oriented sections taken successively nearer to the posterior edges of the organ one can see the development of evaginated flaps of epithelium-covered mesoderm that nearly meet over the photogenic cells in C and are completed as an unspecialized layer in the last drawing,

D. This evaginated and consolidated area of mesoderm is now in a position to differentiate all or any of the structures that we shall see later in the squids, and that lie between the source of light and its point of exit from the body. These consist of lens, color screens and cornea, besides other less specific structures, such as blood-spaces, muscle tracts, etc.

The cranchids have thus, in their adult light organs, furnished us with the strongest indications, if not the actual proofs, of the

FIG. 6.



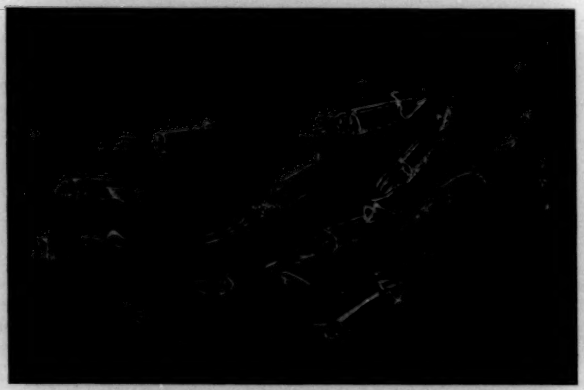
Two other ocular organs from *Leachia cyclura*. These show the complete covering of the epithelial light-cells by mesodermal connective tissue to form a cornea. Chromatophores are present in this cornea. A is the result of a single invagination, one of whose epithelial lips is still visible. B is the result of several adjoining invaginations, as shown by the cords of cells. (After Joubin.)

ectodermal origin of all of the cephalopod light-cells. A further study of the embryonic and larval stages of some of the higher and much more complicated organs is desirable in order to complete our knowledge of this subject.

We are now at liberty to take up the study of the numerous more complicated forms of light organs in other families of squids with a better understanding of their meaning. This can be done with most interest and profit by describing the entire lighting systems of several of the numerous forms.

Fig. 6, A and B, shows two light organs, also from the eye region in *Leachia cycluria*, in which the occlusion of the photogenic cells is completed at every point. A shows such an organ that invaginated at one point only and in which the transitional epithelium is still plainly visible at the lower side of the invagination. B shows an organ that was undoubtedly derived from a multiple invagination which is as complete as the organ shown in A, so far as being covered by mesodermal tissues is concerned. The cords and rows of cells due to the several neighboring invaginations are plainly visible in the drawing.

FIG. 7.



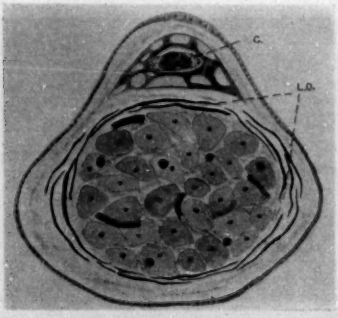
A school of squids, *Watasenia scintillans*, as they appear when alive and illuminating. (Drawn by E. Grace White after descriptions by Sasaki and others.)

The next study and discussion will be of the two Œgopsid squids, *Watasenia scintillans* and *Abraliopsis morisii*, the first being a common and abundant deep-water form found on the coast of Japan, and the latter in various parts of the South Atlantic and Indian Oceans, at great depths, where it is probably common enough but very hard to procure by our present fishing methods. Fig. 7 is a drawing of the appearance of *Watasenia* in life when shining.

Leaving out all other points of relationship, it is very apparent

that both these squids are possessed of practically the same luminous organs. These are of three kinds in both cases: a large number (several hundreds) of small, round light organs scattered over the ventral surface and sides of the mantle and outer surfaces of the more ventral arms; five much larger organs found in a row on the ventral surface of each eyeball; and, lastly, three very large and powerful organs placed in a close-set row on the internal tip of each of the two ventral arms. Of these three kinds of organs, those found on the ventral arms are by far the most

FIG. 8.



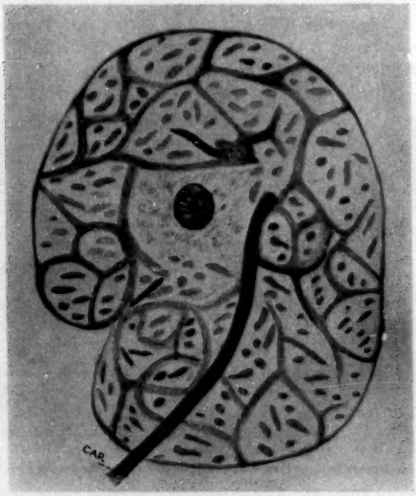
Transection of one of the brachial light organs of *Watasenia*. *c.*, nerve-cord; *l. o.*, light-organ surrounded by chromatophores. (Drawn by E. Grace White from sections.)

powerful and most highly specialized physiologically. In spite of this, however, they are the most simple structurally and represent a condition but little advanced upon the simple epithelial organs found in the cranchids. Fig. 8 shows one of these organs from *Watasenia* cut in a transverse section of the arm. The tissues of the arm appear as a nerve cord (*c*) with the surrounding muscle connective and epithelial tissues, and on the inner side is the large luminous organ (*l. o.*), which is much larger in diameter than the arm it is partly imbedded in.

In structure it consists of a large, globular mass of photogenic cells of great size (about 50 microns), packed rather closely together and almost surrounded by a layer of heavy chromatophores.

Each cell (Fig. 9) contains a single central nucleus of considerable size, with a typical chromatin pattern of large-sized particles surrounded by a narrow zone of a delicate and undifferentiated cytoplasm. The large bulk of peripheral cytoplasm is composed of much denser strands and loops closely interwoven and containing between these strands and loops a large number of spaces

FIG. 9.



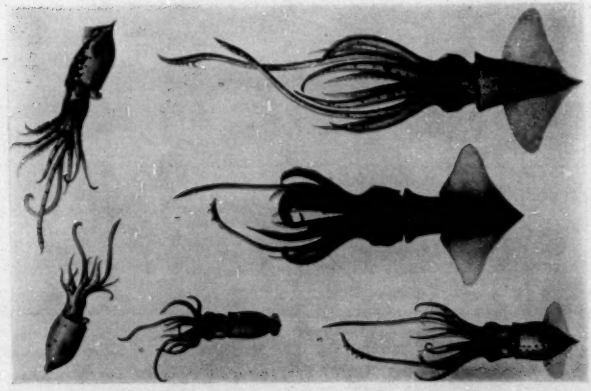
One of the light-cells from the brachial organ of *Watasenia*. Shows nucleus in centre, strand-like arrangement of cytoplasm, and capillary (*cap.*) entering and branching in cell-body. (Drawn by E. Grace White from section.)

which were vacant in the rather poorly preserved specimens in the writer's possession. No granules appeared to be present, and it is supposed that the luciferine which these cells must have undoubtedly contained was in a fluid form that was dissolved out by the method of fixation (weak formalin).

An interesting feature of the structure of this tissue was the rich net-work of capillaries that branched through it. The ter-

minal twigs of these capillaries even entered the individual cells and branched into a finer net-work inside of them (*cap.*), thus being in a position not only to effect food, respiratory, and excretory exchanges, but also to supply the oxygen necessary to the chemical method of light production. We know on the best of authority that this organ is really a luminous organ. Its light has been described by Watase, Berry, and Sasaki, and a paper on the subject is in course of preparation by Professor Ishikawa. The light is discharged in all directions as a flash or a series of

FIG. 10.



Figures showing the external appearance of the adult and young of the deep-sea squid *Abraliopsis morisii*. (After Chun.)

flashes, and it is a more powerful light than that of any of the Japanese fire-flies. In color it is bluish-white, with a tinge of purple or violet as described by Sasaki. Fig. 7 shows a school of these squids in motion through the water with their lights showing.

When seen in the daytime, in bright daylight or sunlight, the living organs show a greenish iridescence which points to the presence of some sort of a reflector. Such a reflector, however, does not appear in the rather poor sections at our command, but a very thin reflecting layer might be present on the proximal surfaces of the chromatophores that are found on three sides of the

organ and, to a limited degree, on the fourth. It is doubtless true that when the light process is going on the chromatophores are contracted into almost invisible points. Otherwise the light would be almost cut off.

In his wonderful work on some luminous squids captured by the steamer *Valdivia*, Dr. Carl Chun describes the organization of the squid *Abraliopsis morisii* (Fig. 10) and refers to its homologous gland-like organs of the same number and size and situated on the corresponding ventral arms. Not having been able to observe the creature alive, and not having seen the light, he referred to these structures as gland-like organs of unknown function. He mentioned the possibility that they might be luminous organs, but finally decided that they were not, because the mass of gland-like cells (the structure is almost precisely like that in *Watasenia*) were entirely shut off from the outside by heavy overlapping chromatophores.

This very natural mistake was due to the fact that he did not realize how contractile and expansible the chromatophores are. We know that a squid can become entirely red or brown by expanding the chromatophores, or entirely transparent in the next few seconds by contracting them into tiny, widely-separated masses that are invisible to the eye. In this way the *Watasenia scintallans* is observed to shine in bright, quick flashes. Whether this is done by a nervous control of the light process or by a sudden contraction and expansion of the heavy black chromatophores or by a combination of both is not known. Either method seems possible. Thus we can feel sure that in *Abraliopsis* the six brachial organs do light; in fact, arguing from the condition in *Watasenia*, they are the brightest organs in the body.

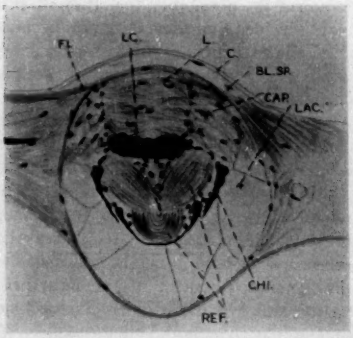
The next organs to be considered are the numerous, minute, bead-like organs found scattered all over the under surface of the mantle and extending out on to the outer surfaces of the ventral arms, and with some few even extending to the upper surface of the mantle. This type of organ is found, with some structural differences, in both the forms we are studying. We will examine the structures as shown in *Abraliopsis*, where it is somewhat better formed than in *Watasenia*.

The organs are about ¼ mm. in diameter and look like numerous black eyes with brown pupils set in among the chromatophores. When cut out and freed from surrounding tissue they

are almost round in shape, with an outer capsule holding its spherical form partly through the tension of the contained fluids. In a section taken through its centre and at right angles to the mantle surface we see a set of structures appearing like Fig. 11. This is a very highly specialized and well-differentiated organ, and yet one the major part of which can be correctly designated and its use explained, in part at least.

The outer surface of the organ is uppermost in the figure, a condition that is the opposite of what obtains in life, when, of

FIG. 11.



Vertical median section of one of the mantle light-organs of *Abraliopsis morisii*. *lac.*, lacunæ; *ch.*, chromatophores; *ref.*, reflectors; *l. c.*, light-cells; *l.*, lens; *fi.*, fibrillar support; *bl. sp.*, blood-space; *c.*, cornea. (After Chun.)

course, it faces downward. The outermost structure is a thin, tough membrane of connective tissue, bearing a very thin epithelium on its outer surface. This is the cornea, *c.* A space, *bl. sp.*, of some extent lies just inside of this and appears to contain blood or some other nutrient fluid, probably not directly connected with the general circulation, as under these circumstances the pressure would probably not be sufficient to maintain the tension necessary for the protection of the inner structures.

Inside of the blood-space comes the lens, *l.*, which is cylindrical in shape, with its outer surface in contact with the blood-space and its inner in contact with the principal mass of light-cells, *l. c.* This

lens shows both outer and inner surfaces to be convex. It is made up of flat plates of connective tissue, slightly curved and interwoven, and the nuclei are somewhat flattened in the direction of the plates. The index of refraction and focussing power of the lens have not been investigated—a research that would prove most interesting and profitable.

Surrounding the lens at its sides and forming a thick ring around it is a mass of tissue containing capillaries, connective-tissue fibres, and probably muscle-fibres. Its relation to the lens reminds one somewhat of the muscle-ring around the inner lens of the light organ of the crustacean *Nyctiphanes*, and if muscle-fibres are present their action would obviously change the focus of the lens.

Inside of the lens again is found the principal mass of photogenic cells, *l. c.*, forming a round plate of about one-fourth the thickness of the lens and composed of a mass of gland-cells whose limits are weakly defined. Their nuclei are large and round, and the cytoplasm has characteristic secretion granules, probably of luciferine. Fine capillaries are numerous between the cells, and their nuclei are elongate, thin, and dark staining. An injection of these vessels would be desirable to establish their courses and ramifications more plainly. The photogenic mass is slightly concave with reference to the outer direction.

Reaching proximal from this light-cell mass is seen a small, triangular mass of apparently less specialized cells, called by Chun the secondary light-cells. The writer feels that this is not a correct designation, and would feel more like concluding that they were cells that were in control of the remarkable set of reflectors found in contact with them. This idea is strengthened by the fact that on the other side of these reflectors is found a thin layer of similar cells whose function is more clearly of this character.

The reflectors themselves, *ref.*, are composed of two sets of hard fibrils or plates, the functional products of the cells above mentioned. One set appears in the form of some eight to ten nested cups, while the others form a series of nested, hollow, truncate cones whose smaller opening coincides with the innermost cup and whose outer opening embraces and is closed by the light-cell mass. Here again we do not know about the character of the reflecting material. Nor can we explain the very definite and peculiar forms of the reflectors themselves.

Proximal to the reflectors, and embracing them, is a cup-shaped mass of chromatophores that act as a final stop for all light that might pass as far backward as they are. These color-bearing cells probably are not contractile, as this would defeat their purpose. It is probably due to their presence that the whole organ as seen from outside gives the impression of having a black iris. The lens, backed by the reflectors, probably shows as the pearl-white pupil.

The last structure to explain is a large, cup-shaped mass of lacunia spaces, *lac.*, which in life undoubtedly contain a fluid. Whether this fluid acts in some nutritive way, or whether it only acts mechanically to maintain the rigidity of the organ's form, is not certain. Both functions could be performed, and possibly are.

Nerve-tissue has not been described in connection with the organ, but is most probably present, sending fibres to the central photogenic mass to control the secretion and combustion of the luciferine.

We will not describe the structure of the homologous organs in *Watasenia* because of the poor material on hand. It is probably built in much the same manner, and we refer the reader to papers about to appear on this subject.

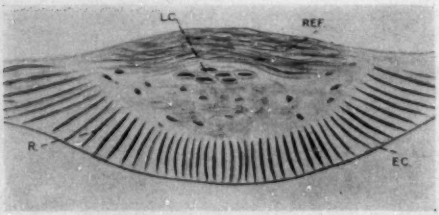
The third type of light organ found in the two squids we are discussing is that which appears as five large spots in a row on the under surface of each eye. They are very much the same in both forms, and we will examine those found in *Watasenia* (Fig. 12).

This organ is wide and flat, and it shows a much simpler structure than the last. Beginning with its outer surface, as we did in the previous case, we find that no lens or separate cornea is present, but the general ectoderm, reinforced by a fine layer of mesodermal connective tissue, forms the smooth boundary (*ec.*). Running inward from this boundary are a series of almost parallel, slightly converging rods (*r.*) of some heavy acid-staining (with eosin or fuchsin) substance. These rods show no visible attending cells, although we know that some nucleated cell is responsible for them. The rods are spindle-shaped, not round, but regularly flattened; they belly out smoothly toward the middle and taper down at both ends to weak staining fibrillar points; at the inner surface of the mass they merge into the mass of connective tissue that forms a flat, disk-shaped mass with thin edges. This mass is

weakly differentiated into three regions that merge somewhat into each other.

Its outer central part is evidently a weakly-formed lens substance slightly resembling the lens structures in the other light organs of the animal. It, too, is a cylinder, but very flat. The cells are much the same, but have not departed so far from the connective-tissue type. The inner central part of the mass is formed into thin, flat luciferine gland-cells (*l. c.*). They form a lens-shaped mass, and their outlines are quite distinct. As a point for the radiation of light they occupy an ideal position, and we can see at once that the rays of light so formed will enjoy a very equable distribution in passing out through the radiating rods spoken of before. This distribution seems to ignore the imper-

FIG. 12.



One of the ocular organs of *Watasenia scintillans*. *ec.*, outer surface of organ; *ref.*, reflector; *l. c*, light-cells; *r.*, rods.

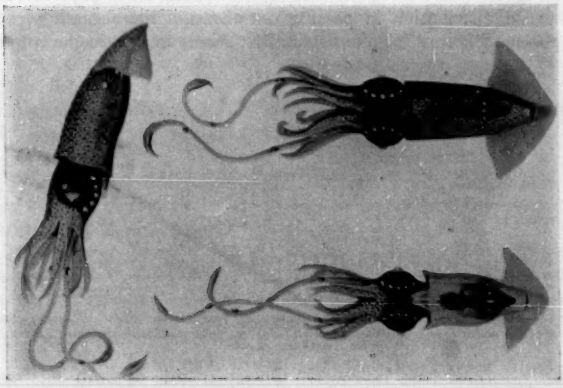
fectly formed lens, however. On either side of both lens and light-cell mass is the usual flat ring of connective tissue containing blood-vessels. It does not appear of much importance in this case.

The reflector (*ref.*) is of the type described in several cases before. Its plate-like masses of reflecting substance show as concave layers of strands in the sections. These strands are of a different substance from the outer rods, although they stain somewhat like them. No cell-bodies nor even nuclei were visible in the preparation. Such important structures are probably very small, as in many squid tissues.

Chun's descriptions of the ocular organs in *Abraliopsis* differ but little from this. All of the ocular organs are the same, or nearly the same, in both squids.

Among the squids with very highly specialized lights on its body is a rare form, of which only a few specimens have ever been captured, *Thaumatolampas diadema* (Fig. 13). The best studies that have been made are by Dr. Chun on the two beautiful specimens that were drawn up from about 3000 metres in depth in a part of the Indian Ocean. These were alive when secured, and, being at once placed in ice-cold sea-water, they lived for several hours and observations were made upon their light organs in the dark room.

FIG. 13.



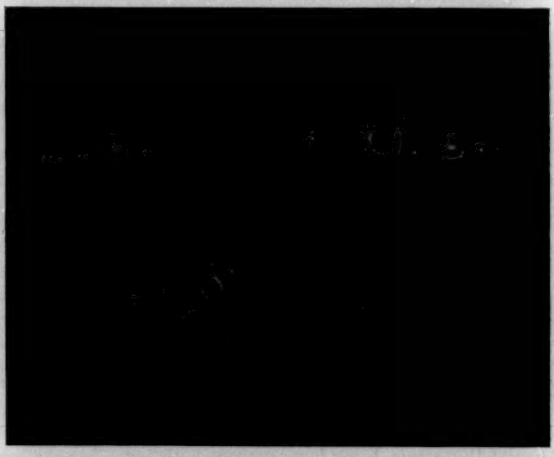
Drawings of the deep-sea squid *Thaumatolampas diadema*. The various (22) light organs appear as little knobs in the locations described in the text.

Each animal showed twenty-two large single organs on its body surface. These were distributed as follows: Two organs on the inner side of each tentacle arm, one about half-way between tip and middle of the arm, and the other about half-way between base and middle; five organs in a curved row (see Fig. 13) on the ventral surface of each of the eyes; two round organs of the same size placed one on each side of the ink-bag and just outside of the nephridial pores on the body surface; five lights placed in a row across the body-complex, the two outer ones being at the bases of the gills; and, lastly, one wide, angular light opposite the extreme

portion of the body-complex, just over the ovary or testis, and lying across the body axis on the inner mantle wall.

When living, these lights glittered so brightly that no difficulty was experienced in making a photographic plate of them; but the remarkable feature was that, while most of them shed a whitish radiance, the two anal lights shone with a clear ruby red, the middle visceral light lit up with a good ultramarine blue, while

FIG. 14



Drawing of *Thaumatolampas diadema* as it would appear in the deep sea when alight. Two individuals swimming, one catching a fish. The last ones show the ventral surface with the lights. (Drawn by R. Bruce Horsfall.)

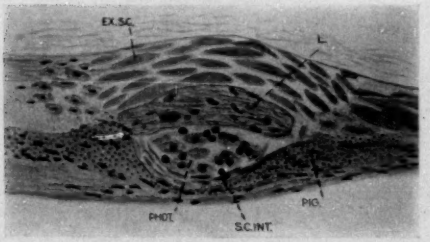
the two middle ocular lights displayed a clear sky blue. The question of how these colors were produced will come up when describing the organs in detail. (Fig. 14 gives some idea of the appearance of these animals when alive and shining.)

All these twenty-two organs are quite complex in structure and also of such variable complexity that a classification is hardly possible. Chun does classify them as to the principles on which they are constructed, but he had to arrange ten classes for the twenty-two lights! We will, then, simply describe the structure

of several of them, naming the known parts according to function, and describing those that cannot be easily identified. In some cases Chun said that he could not, with certainty, identify even the light-cells.

The distal tentacle organ shows a peculiar tendency, found in this and some other squids as well as in some fishes, to duplicate or multiply its light organs in the axis of light emission. The principal organ at this point is a large, rounded mass of light-cells arranged much as in *Watasenia* and with as simple or a simpler arrangement as to accessory structures, there not being any, not even the surrounding shield of dark chromatophores. The

FIG. 15.



Vertical section of the under member of one of the double-eye organs of *Thaumatolampas*. *ex. s. c.*, external "scale-cells"; *l.*, lens; *pig.*, pigmented cells; *phot.*, photogenic or light-cells; *s. c. int.*, internal "scale-cells." (After Chun.)

cells of this organ are considerably different in structure from those of *Watasenia*, being homogeneous with some few shallow indentations on the edge to allow of the passage of capillaries and nerves between them. Some of these indentations are deeper and may represent peripheral vacuoles in which luciferine combustion takes place. Numerous nerves and blood-vessels enter this very large mass of photogenic cells.

The nerve-cord of the arm lies on one side of this mass, and on the other lies a more peripheral light organ, more of the type of the other organs found on the body. It shows a small body of light-cells and a very large mass of corneal and reflecting cells surrounding this mass. We will not describe its structure further, merely calling attention to the fact that it has no connection with

the large central organs, but appears to have been added to them by later evolutionary processes along with the other highly specialized organs on the rest of the body.

Another interesting organ is the one found on each end (anterior and posterior) of the row of five organs on the ventral side of each eye. This, like the last, is a double organ, one placed at the surface and the other directly beneath it. Of the two, the inner, while smaller, is the most perfect, and we will examine it in the usual vertical median section (Fig. 15).

The specific cells of this organ are the group of photogenic cells found in the figure at *phot.* They are like those previously described with a good supply of capillaries and nerves. The mass rests in a shallow, cup-shaped layer of biconvex, lens-shaped cells which appear in section as spindle-shaped (*s. c.*). This cell is a heavy mass of cytoplasm with a small, flat nucleus on one side and its cytoplasm filled with a series of closely-applied flat plates of some firm, dark-staining substance. These plates are for the purpose of handling light in some way, but, owing to the fact that they appear both below and above the light-cells, the problem cannot be solved without further study. Light passes through the outer layer; that is certain. Possibly they possess lines that act as a diffraction grating in whichever direction the light strikes them. Beneath these " scale-cells " lie mesodermal cells that contain a brown pigment (*pig.*). This evidently acts to prevent the further contact of the light with the ordinary tissues of the eye.

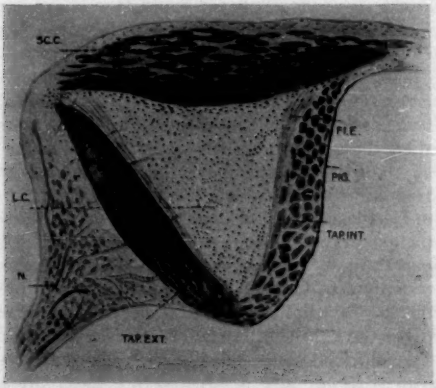
Outside of the light-cells is found a flat layer of fibrous cells of a definite color and somewhat like the cells of the lens in the mantle organ of *Abraliopsis.* This structure may represent a lens in spite of the small use that a lens would appear to have in this location (*l.*). The cell boundaries are not visible, and the fibrils of the tissue appear to reach from side to side of the structure, pursuing a curved or winding course, although they are not matted or wound up with each other.

Outside of this lens structure comes the thick layer of external " scale-cells," with their layers of plates (*ex. s.c.*), the same kind as those below the light-cells, but more than twice their size in diameter. This layer represents the outside of the organ and rests against the light-cells of the outer portion of the entire organ (not shown in the figure).

This outer and larger part of the organ will not be discussed

except to call attention to the fact that its outer layer of cells ("scale-cells," too) does not entirely cover the light-cells, which on the median edge of the organ reach to the surface, thus giving a clew to their ectodermal origin. The writer hopes that such an origin will some time be proved when the embryos and larvæ of this interesting squid can be secured by a diligent use of the vertical net. This should be possible when the nations take up science again instead of war and send out the deep-sea expeditions that have shown us so much of interest and value.

FIG 16.



Median section of one of the anal light organs of *Thaumatolampas*. *sc. c.*, scale-cells; *l. c.*, light-cells; *tap. int.*, internal tapetum; *tap. ext.*, external tapetum; *n.*, nerves going to light-cells through external tapetum; *pig.*, pigment layer on inside of internal tapetum; *fi. c.*, fibrous cells of lamellar layer. (After Chun.)

The two large, red anal light organs will next claim our attention. The most interesting point about them is that they are ruby red, both when not lighting and seen by daylight and also when shining in the dark by their own light. The structure shows some interesting points, but also many that are not yet explainable. In Fig. 13 may be seen the organ as it appears from the ventral side before the mantle has been cut away. Fig. 16 is a drawing of a median vertical section that gives a good idea of its general structure.

The light-cells appear here as a large, triangular mass, one of the largest masses of light-cells seen in any of the organs of this squid. In structure these photogenic cells are much the same in all of the organs of this squid. Only in external form and size do they differ, some being compact and large, while others have become more or less elongate, as may be seen in parts of the middle ocular organ.

The triangular mass of light-cells is lined on its two internal surfaces by a layer of connective-tissue cells whose cytoplasm has developed fine lamellæ that lie parallel with the surfaces of the mass (Fig. 16, *fi.c.*). These lamellæ are represented by lines in this view where they are cut in cross-section. The nuclei of the cells, whose boundaries are not discernible, are round, and they are distributed at regular intervals through the mass. The outer (laterad) and inner (mediad) lamellar cells form a thicker mass in the ventral part than in the dorsal part of the organ. Their meaning is uncertain. They do not seem to indicate a reflection function, and may be merely connective in their operation.

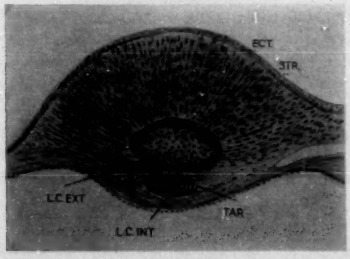
Outside of these again comes the tapetal layer, which is thick and composed of more massive cells with a coarsely granular content (Fig. 16, *tap. ext.* and *tap. int.*). A marked difference exists between the outer and inner portion of this layer on the two sides of the organ. The cells of the inner portion are larger and more compact, and in unstained sections show no pigment. Those of the outer layer are similar, flatter, and a brown pigment is mixed with their granules. The main nerve and blood supply comes from the lateral direction and runs mediad through this pigmented layer to enter the light-cell mass, then to branch and distribute itself among the light-cells. The tapetal cells appear to be the chief reflector cells of the organ. Those on the inner side of the organ are lined on their proximal surface by a thin layer of dark pigment which seems to fulfil the function of light absorption on this side, as the lighter pigment scattered in the outer tapetal cells must do on the outer lateral surface.

Ventrad from the light-cell mass and on its external surface (upper surface in Fig. 16) is a thick layer of the "scale-cells" of much the same structure as those described in the last organ. Since the light must pass through them, they may have much to do with its red color, although it would seem probable that the red pigment on the extreme outer surface of the organ (not shown in the sections) was the ray filter that did this.

When some scientist again has the valuable opportunity to handle a living and shining specimen this outer layer should be carefully scraped with a fine scalpel or needle to see if a white light is filtered through the red surface of the organ, or if the chemical processes taking place in the light-cells result in the red-colored light. That a white light should come from one organ of an organism and a red light from another is quite possible, as it actually occurs in an insect (*Phengodes*) to be described in a forthcoming chapter. This red-light organ offers great opportunities for careful experimental studies.

One more light organ must be studied in this wonderful animal because it involves an entirely different principle of structure.

FIG. 17.



Longitudinal vertical section of middle ventral light organ of *Thaumatolampas*. *l.c. int.*, light-cells of inner organ; *l.c. ext.*, light-cells of external light organ; *tap.*, epithelium-like tapetum; *str.*, rod layer resembling that in ocular organ of *Watasenia*; *ect.*, epithelium layer on outside of organ. (After Chun.)

That is the middle ventral organ, which shines with a clear blue light. This also is a double light, as some of the others are (Fig. 17). Its outer organ contains a rounded mass of light-cells resting proximally on the " scale-cells " of the inner organ. Its structure is simpler than that of the anal organ. Outside of the light mass is a wide, thick zone of cells that have formed long rods (Fig. 17, *str.*) of some firm substance, that run at right angles from the surface of the light-cell mass out to the epithelium that covers the whole distal surface of the organ. In this structure the organ reminds us of the ocular organ of *Abraliopsis*, and the function of the rods is probably the same—to distribute the light as a glow rather than to do the same by means of a lens.

The inner part of this ventral organ consists of another and far smaller mass of light-cells (*l. c. int.*) surrounded by small "scale-cells" on all sides except its ventral side, where, between the "scale-cells" and the surface of the light-cells, is a layer of long epithelial cells containing pigment and with their nucleus at the distal end of the cell (*tap.*). Or, to put it another way, the epithelium appears to have become inverted, probably by some of the invagination processes by which the organ was formed, and the nuclei are in the histologically proximal ends of the cells, although morphologically they are distal.

The above will give the reader some idea of the wonderful complexity and efficiency of the squid light organs and the necessity of further careful study in order that we may understand them better. This work must be done, as has already been stated, on a properly-fitted-out boat of size sufficient to enable the workers to remain at sea and study the specimens when captured.

Many other squids might be described, did space permit, with numerous organs built on many other principles of construction, but we must now leave all this class of cephalopods with light organs of the internal-combustion kind and go back to our beginning from the cranchid squids and take up the forms with the light organs of external combustion. There are comparatively few of these, nor will we be able to find any of a really simple character, such as those in which the organ is represented by a still open simple invagination. However, such a form will probably be discovered in the future when better facilities for work can be found.

ORGANS OF EXTERNAL COMBUSTION.

The two cephalopods that will serve us for examples of this type are *Heteroteuthis impar* and *Sepietta minor;* and these two will be described together because in the one case (*Heteroteuthis impar*) the writer has observed the living animal in action but was unable to secure material for histological study, while in the other (*Sepietta minor*) well-fixed material was obtained, although the activities of the squid were not actually observed. The structures of its organ, however, show that *Sepietta* must light very much, if not exactly, in the manner that *Heteroteuthis* does.

Heteroteuthis impar is a small and very beautiful squid found occasionally in the Bay of Naples and said to be more abundant off the more southern coasts of Italy. When brought into the

laboratory in good condition and allowed to rest quietly it may be taken into the dark-room and gently struck, as it swims in the aquarium, with a glass rod. Fig. 18 is a drawing to illustrate what may and usually does happen under these circumstances. The animal throws out of its siphon several little masses of mucus which show no light at the moment of ejection, but almost instantly, as the oxygen of the water begins to work on them, show a number of rod-shaped particles of a brilliantly luminous matter embedded throughout the very delicate mass. As the mass con-

FIG. 18.

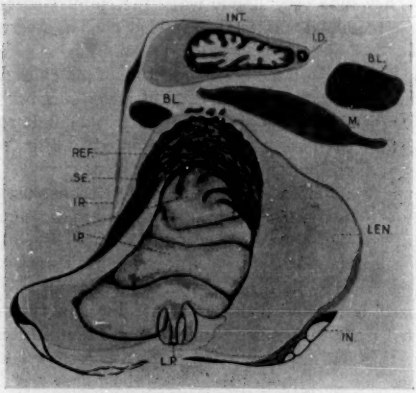
Drawing of a squid (as *Heteroteuthis impar* or *Sepiella minor*) when it lights by the external secretion method. (From a drawing by R. Bruce Horsfall, after descriptions by the writer, based on observations of *Heteroteuthis impar*.)

tinues to expand this light continues to glow brightly for as much as three to five minutes, after which it rather suddenly dies out. In color the light is the usual blue-green of luciferine when burning outside the body. The animal can repeat this process for a number of times, when it appears to have exhausted its supply of luciferine, and it is not possible, apparently, to keep it in captivity for a long enough period for the supply to be restored. A short and superficial morphological account of the structure of the gland which performs this function has been written by T. Meyer.

In place of this form we will turn for the structural details to the small squid, *Sepietta minor*, of which the writer secured good histological material at the Naples Zoological Station, in the deeper water of the Bay of Naples.

Upon opening the mantle of one of these little animals from the ventral side two bean-shaped, white masses are visible on the ventral surface of the pallial complex and placed symmetrically on each side of, and a little below, the anal opening. They lie against the sides of the ink-bag, and the reservoir of this ink-bag is extended to form a covering for the ventral side of the white mass.

FIG 19



Vertical section through the anal region of *Sepiella minor* to show the relation of the light organ. *int.*, intestine; *i. d.*, ink-duct; *m.*, muscle; *bl.*, blood; *i. p.* (upper figures), ink reservoir; *ref.*, reflector; *se.* secretory epithelium of light-gland; *l. p.* (lower figures), luciferine reservoir of light-gland; *l. p.*, papilla through which luciferine is ejected; *len.*, lens.

A transverse section through this structure at about its anterior third shows a very interesting picture under the low-power objective (Fig. 19). The organ consists of two somewhat independent parts. The first of these is a very large lens (*len.*, Fig. 19), composed of a jelly-like connective tissue which appears fibrous when fixed and stained in section, but which in life is quite transparent. The brilliant white color of the organ in life is

due to a reflector layer (Fig. 19, *ref.*) on the dorsal or inner surface of this lens.

This reflector does not lie entirely against the lens, however, but only partly so, its middle portion being separated from the lens by the secretory organ of the gland. In Fig. 19 the reflector embraces this secretory portion more exactly and reverses its edge when it touches the lens. The reflector is made up of large, stout fibrils of a dense, dark-staining substance. These fibrils run in various directions, so that both longitudinal and transverse sections as well as oblique sections are visible in almost any section of the organ. In staining capacity they resemble the blood almost exactly when fixed in Bouin's fluid and stained with iron hæmatoxylin. They fade very slowly when the stain is extracted too much, while the blood masses fade suddenly when a certain point is reached.

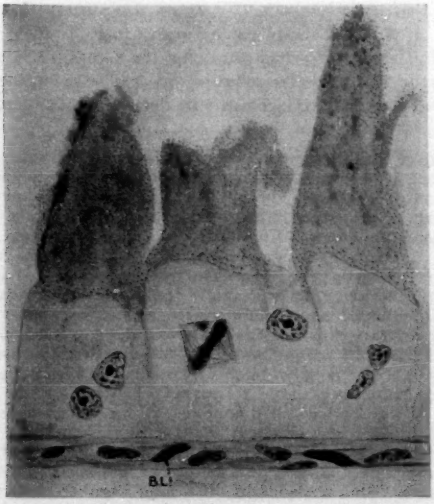
The specific cells of the organ form a simple epithelium that has been invaginated from a single point into a number of large, flat, sac-like glands lying next to each other in a single row. The lumina of four of these sacs are represented in Fig. 19 by the cavities, two of which are marked, *i. p.* (lower figures). In those of a secondary amplification are present. Reconstruction from serial sections shows that all of these sacs open at a common point by separate openings through the papilla (Fig. 19, *l. p.*), which opens into the mantle cavity from the ventral surface of the organ to one side of the lens. This papilla is muscular and is tightly closed, but shows bodies of luciferine in its ducts. Material ejected from this papilla would be thrown into the excurrent siphon and thus out into the water, just as in *Heteroteuthis;* it is very difficult, however, to see this light, as the animals seem to have exhausted the power before arriving at the surface. Some small amount has been seen by the collectors of the Naples Zoological Station.

The presence of the lens would seem to indicate that some of the light was produced inside the sac-like glands. Such a lens would be of no use whatever if the luciferine burned only when it had reached the external sea-water outside of the animal's body. On the other hand, the presence of the papilla shows that something must be ejected. Possibly only the products of combustion are thus thrown out. The third possibility is that both methods are used, which, however, is rather unlikely. A few experiments

ought to solve this question, if one would perform them at Naples or elsewhere.

The secretory epithelium of these glands is shown in Fig. 20. It consists of large, cubical cells, most of which contain two nuclei placed obliquely in the cell. The cytoplasm is clear and no secretory granules are visible until near the distal surface of the cell, where they suddenly appear and form dense masses of the fine

FIG. 20.



Three cells from the secretory epithelium of the luciferine gland of *Sepiella minor*. *bl.*, blood-vessels. Nuclei are shown, one mitotic figure, and the distal mass of secretion.

brown granular secretion which partly fills the lumen of the gland. The cells form a single row and show many signs of exhaustion and degeneration from their work. Many of them collapse and are thrown off into the secretion. Others lose portions of their distal cytoplasm, which appears in lumps in the secretion. Of course, this means that there must be a constant regeneration of the epithelium, and we find a considerable number of mitotic figures in

the cells, one of which is shown in Fig. 20. It is evident that this division will result in two nuclei which will be placed at different levels in the cell, as are the two nuclei in the neighboring cells. Of the two nuclei, that which produced the outer one will probably degenerate after a short period of work and be thrown off with a portion of the cell, while the other will renew its activity by another division. Cell boundaries are very difficult to see in these large plastic cells.

The writer regrets that space forbids descriptions and discussions of the numerous other types of these beautiful luminous animals. It will well repay any naturalist to study them when the needful but expensive apparatus for their capture is available. Many hundreds of species swim in the deep seas, on the surface, and in the intermediate layers of the deeper oceans of the world.

To Make Soil Pressure Tests. (Office of Information, U. S. Department of Agriculture, February, 1916.)—Experiments on the distribution of pressures through soils are to be conducted at the Government's Arlington Farm, near Washington, by the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture. A specially-designed apparatus will be installed which will permit of earth-pressure measurements being taken in a large number of positions during a single application of the load. This feature is regarded as an important one, and it is hoped that an unnatural rearrangement of the soil from previous load applications in various positions will be thus avoided. Earth fills up to ten feet thick may be accommodated by this apparatus, and it will have lateral dimensions sufficiently large to permit of obtaining the full distribution of the load in all directions. Very comprehensive plans have been made for a practical solution of this problem, and it is hoped that definite results will be forthcoming within a short time.

The uncertainty of the distribution of pressures through soils, both vertically and horizontally, has long been recognized by the engineering profession, and several isolated experiments have been made with laboratory apparatus to gain knowledge on this subject. In magnitude the problem is such that its practical solution can be attempted only by the most thoroughly-equipped experiment stations. In application the final solution will be important to all branches of engineering, and it has seemed desirable that the department should devote a portion of its experimental resources to a most thorough and conclusive research of this nature.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE ILLUMINATION FROM A RADIATING DISK.†

By Paul D. Foote.

[ABSTRACT.]

THE consideration of the illumination from a radiating disk is of some practical value to engineers. Because of the fact that certain solutions of this problem which have appeared in technical journals have been in error, it was thought desirable to present the correct solution in a convenient and readily accessible form. The solution gives the illumination produced by a diffusely and uniformly radiating circular disk at any point in space on a surface parallel to the disk.

PHOTOMETRY OF THE GAS-FILLED LAMP.‡

By G. W. Middlekauff and J. F. Skogland.

[ABSTRACT.]

THE new high efficiency gas-filled lamp introduces variables not hitherto encountered in the photometry of incandescent electric lamps. On account of the comparative broadness of the filament spiral and the dyssymmetry of the filament mounting, there is considerable irregularity in the distribution of the light about the vertical axis. Consequently, when the lamp is rotated, as is commonly done in rating lamps at the factory, the light as seen in the photometer flickers so excessively as to render accurate measurements of candle-power practically impossible without the use of auxiliary apparatus. However, as is sometimes done, if two mirrors inclined to each other be placed back of the lamp, the flickering is so much reduced as to permit accurate candle-power measurements even at very low speeds of rotation.

* Communicated by the Director.

† Scientific Paper No. 263.

‡ Scientific Paper No. 264.

But this expedient does not eliminate the most serious trouble caused by rotation. It was found that at constant voltage both the current consumed and the candle-power are different when the lamp is rotating than when it is stationary, the current changing in one direction and the candle-power always in the opposite direction; that is, there is a change in the operating efficiency of the lamp. Furthermore, this change in efficiency may be either positive or negative, depending upon the speed, and it is about twice as great when the lamp is rotating tip up as when it is tip down.

Fortunately, from the standpoint of photometry, there is for each lamp in either position a particular speed at which the current and the candle-power have the same values, respectively, as when the lamp is stationary. Hence, with the lamp rotating at this speed its candle-power can be measured with accuracy in spite of its rotation. The speed for the above condition is practically the same for all lamps having the same number of loops in the filament; but for lamps having different forms of filament mounting it varies from lamp to lamp, being greatest for those having the smallest number of loops in the filament.

If the above precaution as to speed adjustment is not observed and lamps are rated while rotating at speeds ordinarily used in photometering vacuum lamps, the errors which enter may amount to as much as 1 to 2 per cent. in current, or watts, in one direction, and as much as 15 to 20 per cent. in candle-power in the opposite direction. Hence the voltage found for a desired operating efficiency may be so much in error as to give a lamp on test at this rated voltage a fictitious life value three or four times as large as the lamp would give if it were operated stationary at a voltage corresponding to that efficiency which, during the rating, was only apparent; that is, the lamp may be given credit for a much longer life than it really deserves. On the other hand, the speed may be such as to cause errors in the opposite direction, resulting in a lamp life much shorter than would be expected from the apparent efficiency rating.

Another peculiarity of the gas-filled lamp is that while it burns the blackening occurs, not all over the bulb in approximate proportion of the light distribution, as in the vacuum lamp, but principally at the top of the bulb, because the volatilized material is carried upward by the gas. Hence, in making a life test, a

true measure of the reduction in total light during the life of the lamp cannot be obtained in the usual manner by means of horizontal candle-power measurements, but by determinations of the total flux or mean spherical candle-power. This is accomplished most rapidly and conveniently by means of an integrating photometer, such as the Ulbricht sphere, in which the lamp is measured stationary, and thus all the complications arising from rotation are entirely avoided.

As to the cause of the variations observed in candle-power and efficiency when the lamp is rotated, it is concluded, from the results of a number of special tests, that the whole effect is produced by a change in the convection currents of the gas, a consequent variation in the temperature distribution in the bulb resulting in a change in the resistance, and therefore a variation in the current and candle-power of the lamp.

THE EFFECT OF IMPERFECT DIELECTRICS IN THE FIELD OF A RADIOTELEGRAPHIC ANTENNA.*

By J. M. Miller.

It has been shown by the measurements of C. Fischer and L. W. Austin that the curve which represents the variation of the resistance of an antenna with the wave-length of the oscillation has two characteristic features. Starting from the wave-length corresponding to the fundamental of the antenna, the resistance of the antenna rapidly decreases with increasing wave-length and reaches a minimum. As the wave-length is still further increased the resistance rises again, but in a linear manner. The initial decrease in resistance is explained by a decrease in the so-called "radiation resistance." It has been difficult, however, to account for the linear increase which takes place at the longer wave-lengths, and it is with the explanation of this feature that the paper is concerned.

Austin has offered an explanation of this phenomenon in that it is caused by dielectric absorption, and also concludes that it takes place in the ground. The present paper confirms Austin's hypothesis with respect to dielectric absorption, but finds that the energy loss is not caused by the ground, but by the presence of poor dielectrics in the field of the antenna. This conclusion

* Scientific Paper No. 269.

is based upon the measurements of resistance of an experimental antenna constructed so as to eliminate poor dielectrics from its field and at the same time increase any effects which may be due to the ground. The linear rise in resistance at very long wave-lengths (even at telephone frequencies) was extremely small. It was then shown that the linear increase became considerable when poor dielectrics, such as wooden masts, trees, and buildings, were in the field, and that the resistance of the antenna was also increased at all wave-lengths. It was also shown that considerable energy loss may be occasioned by running the lead of an antenna inside of a building. The importance of designing an antenna so as to minimize the above sources of energy loss is pointed out.

LUMINOSITY OF A BLACK BODY AND TEMPERATURE.*

By Paul D. Foote and C. O. Fairchild.

[ABSTRACT.]

THE so-called "effective" or Crova wave-length of the luminosity of a black body may be considered a function of the temperature as follows: $\lambda_L = a + b/\theta + c/\theta^2 + \ldots$ The relation between luminosity, L, and effective wave-length is shown to be of the following form:

$$\frac{d \log L}{d\theta} = \frac{c_2}{\theta^2} \cdot \frac{1}{\lambda_L}$$

If $\lambda_L = a$, the temperature-luminosity relation takes the form suggested by Rasch. If $\lambda_L = a + b/\theta$, the relation is the Nutting equation. If $\lambda_L = a + b/\theta + c/\theta^2$, a new equation is obtained which is slightly more accurate than the Nutting equation. The three equations were checked by computations of the luminosity at various temperatures from the relation $L = \int_0^\infty VJd\lambda$ where $V =$ the visibility function and J represents the Wien spectral distribution law. The Nutting equation followed the computations satisfactorily; the new equation showed deviations no larger than errors involved in the computation of the luminosity, while the Rasch relation proved totally unsatisfactory

A luminosity pyrometer with a calibration based upon either the Nutting equation or the new equation should prove advantageous for the measurement of high temperatures.

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* Scientific Paper No. 270.

INCLUSIONS IN THE SILVER VOLTAMETER DEPOSITS.*

By G. W. Vinal and W. M. Bovard.

FOR the purpose of determining the absolute value of the electrochemical equivalent of silver and the absolute value of the faraday it is necessary to learn the amount of "inclusions" in the silver voltameter deposits. Several methods have been used in the past, but the results have been contradictory and uncertain. Lord Rayleigh [1] advocated heating the platinum cups with deposits to incipient redness as the simplest method of expelling the inclusions, which are chiefly water and silver nitrate. Richards and Anderegg [2] have recently used this method also, finding the inclusions to be large and variable in amount. We have repeated their experiments of heating the cups with deposits in a flame and have also made for comparison heatings in an electric furnace which was designed and constructed for this work by Prof. G. A. Hulett.

Preliminary tests on the empty platinum cups showed that they could be heated by either means and remain sufficiently constant in weight. When silver deposits are heated in the platinum cups alloying of the two metals takes place. This is slight if the time of heating is very short, or it may become pronounced as the time is increased. On removing the silver, the platinum cup shows stains which are brownish if the alloying has been slight, or black if heavily alloyed. Nearly all previous observers have noticed the alloying and one, Van Dijk,[3] has described the stains. But none of the previous observers seem to have been aware of the nature of these stains and the serious errors which they may introduce in the quantitative results. Our work has led us to conclude that these stains are platinum black and that they render the weight of the empty platinum crucible very uncertain unless the precaution is taken to heat the cups to incandescence, or to remove them by *aqua regia* before making further deposits. This heating process transforms the platinum

* Scientific Paper No. 271. (Complete paper to be published in the *Bulletin of the Bureau of Standards.*)

[1] *Phil. Trans. A.*, 175, p. 411, 1884.

[2] *J. Am. Chem. Soc.*, 37, p. 15, 1915.

[3] *Arch. Neer des Sci.*, ii, 10, p. 277.

black to platinum gray, and the loss in weight apparently suffered by the cups may be anything from 0.1 mg. to 5.0 mg., depending on the amount of material adsorbed by the platinum black. If the silver deposits had been made before this heating it is apparent that the losses in weight observed on subsequent heating could not properly be ascribed to the expulsion of the inclusions in the silver, as assumed by previous observers, since it would in part be due to the expulsion of dissolved material from the stains. The presence of either platinum black or platinum gray in the cup renders the cup unfit for use in measuring the electric current, since they exercise a catalytic action on the hydrogen ions present in the solution and therefore the amount of silver deposited is too small to represent all of the electricity which actually passed through the voltameter.

Taking these sources of error into consideration, we have made determinations of the losses in weight of deposits from pure electrolyte and find as follows:

	Per cent.
Mean 16 flame determinations	0.0041
Mean 9 furnace determinations	0.0038
Mean of all determinations	0.0040
Probable error of mean result	0.0003

With less pure electrolytes the losses are greater.

The Bureau of Standards published some time ago an absolute value[4] for the electrochemical equivalent of silver which was obtained by the silver voltameters containing especially pure electrolyte and an absolute current balance of the Rayleigh type. The value found was 1.11805 mg. per coulomb, which may be now corrected by subtracting 0.0040 per cent., and thus it appears that the value 1.11800 mg. per coulomb, which was adopted by the International Electrical Conference in 1908, is in reality within one part in one hundred thousand of the best value which we can now assign to this constant. On this basis we may compute the value of the faraday, using the present value for the atomic weight of silver (107.88), and find the faraday to be 96,494 coulombs. For general purposes the round number 96,500 is recommended.

A number of additional experiments were tried, such as re-

[4] *Bulletin Bureau of Standards* 10, p. 477.

peated heatings of the deposits, the effect of rough and smooth surfaces of the platinum cups, the effect of using voltameters of different sizes, a comparison of heating deposits scraped from the cathode with similar deposits not scraped off, and several experiments on the anode liquid. The results of these various experiments are given in full in the complete paper which will shortly be published.

THE CORRELATION OF THE MECHANICAL AND MAGNETIC PROPERTIES OF STEEL.*

By Chas. W. Burrows.

[ABSTRACT.]

This paper is a review of the work done in correlating the magnetic and mechanical properties of steel with special reference to the commercial application of the magnetic data as criteria of the mechanical fitness of a given steel and of magnetic changes under stress as indications of the state of strain.

A comparison is made between the magnetic properties and the other physical properties of steel. Among the mechanical properties that have been studied in connection with the magnetic characteristics are hardness, toughness, elasticity, tensile strength, and resistance to repeated stresses.

Another important phase of this subject is the variation in magnetic behavior as the test piece is subjected to the influence of stress. The correlation here is so close that the strains set up in a stressed bar are accompanied by simultaneous variations in the magnetic behavior, which change in character as the magnitude of the stress with respect to the elastic limit changes.

The magnetic test has been applied to the detection of flaws. Mechanical inhomogeneities of whatever origin are mirrored by corresponding magnetic inhomogeneities. A magnetic test may therefore be of assistance in detecting flaws in material where the vital characteristic is reliability. The results of the experimental work have been brought together in the form of numerous curves, which show in a concise manner the interrelation between the mechanical and magnetic properties of steel.

* Scientific Paper No. 272. (Complete paper will appear in the *Bulletin of the Bureau of Standards.*)

CONCLUSIONS.

The experimental evidence, of which only a small portion has been presented in this paper, seems to point to the conclusion that there is one, and only one, set of mechanical characteristics corresponding to a given set of magnetic characteristics, and, conversely, there is one, and only one, set of magnetic characteristics corresponding to a given set of mechanical characteristics.

Although there is no evidence to refute the preceding rather broad statement, the utility of this generalization is limited by the complexity of the relations due to the large number of variables and the lack of sufficient quantitative data. This lack of quantitative data, however, is only a temporary limitation and is gradually being overcome by the work of the author and of others who are working on this problem. The application of the magnetic tests is further limited by practical difficulties in testing irregular shapes. Even with these limitations magnetic testing in conjunction with mechanical testing may be expected to be of considerable value in determining mechanical properties.

Magnetic observations taken during the course of a tensile test will indicate the time when the true elastic limit, the yield point, the breaking-down point, and the ultimate strength are reached. In addition, the magnetic data will give some idea of the uniformity of the material.

If it is once determined what treatment is requisite for a given steel, a magnetic test may be used to determine whether or not the material has been brought into the desired condition.

It is quite possible that the magnetic data may be used to define a bar of steel. In no other manner than by a magnetic examination is it possible, without doing violence to the specimens, to determine whether two steel bars are identical in properties.

A determination of the magnetic uniformity of a piece of steel may be used as an index of the mechanical homogeneity.

A magnetic test indicates the character of the entire cross-section of the metal, rather than merely a surface phenomenon, as in the case of certain hardness tests.

Notwithstanding the possibilities of the magnetic test, it must be remembered that at present they are possibilities only. Before the magnetic characteristics can be of much practical importance, a great deal of investigation is necessary and a large number of accurate measurements on specimens of known chemical composition and heat treatment must be made.

Before a magnetic test can be of service as an indicator of the mechanical characteristics in any particular case preliminary work must be done to determine the most suitable magnetic data and also the minimum amount which will give the desired information. Among the magnetic characteristics which may be used are permeability, residual induction, coercive force, hysteresis energy, etc., and each of these may be taken in connection with any one of a great number of magnetizing forces.

GENERAL DESIGN OF CRITICALLY DAMPED GALVANOMETERS.*

By Frank Wenner.

[ABSTRACT.]

The user of a galvanometer is concerned with the conditions under which the damping is good or critical, the time required for the deflection to reach a steady value, or in ballistic work a maximum value, and the sensitivity to the quantity which the galvanometer is used to detect or measure; that is, he is concerned in the performance or operation constants which necessarily depend upon the inertia constant, the damping constant, the restoring constant, the dynamic constant, and the resistance. The latter are the intrinsic or construction constants which depend upon the size, proportions, kind of material, etc., used in the construction and are therefore of interest to the designer and maker of the galvanometers. The relations existing between these two sets of constants are of interest to both the user and maker of galvanometers. They are, however, of more interest to the maker, since they may be made to serve as a basis for predetermining values for the construction constants such as will give specified values for the operation constants.

The paper gives the relations existing between each of the operation constants and the construction constants. This is done for each of four classes of measurements in which galvanometers are used critically damped. In the first of these the sensitivity with which the user of the galvanometer is concerned is to current, in the second it is to voltage, in the third it is to current impulse,

* Scientific Paper No. 273.

and in the fourth it is to voltage impulse. These relations are then used in establishing a procedure for finding a set or sets of values for the construction constants such as will give previously selected or specified values for those of the operation constants which pertain to the class of work in which the galvanometer is to be used. This procedure constitutes what we shall call the general design and is the problem which receives the main consideration.

It is pointed out that in any of these classes of measurements the user is concerned with at most only three operation constants, while the galvanometer has five intrinsic constants. Consequently it must be possible to choose values for some of the intrinsic constants arbitrarily or within definite limits and find values for the others such as will give the specified values for the operation constants.

It is shown that in any case we may choose arbitrarily a value for the resistance. However, in those cases in which the power available in the galvanometer circuit is definitely limited the resistance and air damping should both be made as low as practicable if we wish a high sensitivity, since any power dissipated in the resistance or air friction reduces the amount available for twisting the suspensions or turning the magnet. Having decided upon a value for the resistance, it is shown that an upper limit for the air damping may at once be calculated. Choosing a smaller value and using the equations given, values for the remaining intrinsic constants may be calculated.

Where the constants of the galvanometer can have no appreciable effect upon the magnitude of the current we may choose arbitrarily a value for any other one of the intrinsic constants in addition to the resistance, and by means of equations given calculate values for the remaining intrinsic constants such as will give previously-selected values for those of the operation constants pertaining to the class of measurements in which the galvanometer is to be used.

The finding of a set of values for the construction constants such that the galvanometer will be critically damped, have the desired deflection period or ballistic period, and the desired sensitivity to current, to voltage, to current impulse, or to voltage impulse, under the conditions in which it is to be used, is a matter which cannot be explained fully in a brief abstract. The reader,

therefore, if interested, is referred to the complete paper, copies of which may be obtained after about April 15, on request addressed to the Director, Bureau of Standards, Washington, D. C.

INTERFERENCE MEASUREMENTS OF WAVE-LENGTHS IN THE IRON SPECTRUM (3233 A–6750 A).*

By Keivin Burns, W. F. Meggers, and Paul W. Merrill.

THE wave-lengths of 403 iron lines were measured by means of interferometers. An effort was made to determine standards at intervals of about 10 Ångstroms. This was accomplished in the greater part of the spectrum from 3233 A to 6750 A, in which region the International secondary standards exist. As far as possible, lines of all intensities were measured. These measurements probably constitute as satisfactory a group of standards as can be obtained from this portion of the iron spectrum.

The arc spectrum of iron was used in accordance with the recommendations of the International Wave-length Committee. The method of procedure was that of Buisson and Fabry.[1] Most of the wave-lengths were determined from three or more interferometers, in which the orders of interference ranged from 15,000 to 60,000 waves. The International secondary standards were used in this comparison instead of the fundamental cadmium standard. The former are the means of three independent comparisons with the primary standard, and our use of them probably gives more accurate results than could be obtained by a direct comparison with the primary standard, which would involve the corrections for atmospheric dispersion and the difficult phase change determination. The mean difference between the present observations and the International standards is about one part in four million.

Comparisons with all the grating observations of iron lines which have been made on the I. A. system prove that more secondary standards were needed to obtain the highest accuracy in grating interpolations. Some of the grating observations show a difference in wave-length which is a function of the intensity of the line. The measurements with the interferometer appear to be quite free from this effect.

* Scientific Paper No. 274.

[1] *Journal de Physique*, 7, p. 69, 1908.

Over 600 lines, including those measured, were examined by means of three or more interferometers in order to discover their limiting orders of interference. This gave an idea of the width or sharpness of each line. The data on sharpness were then correlated with intensity, pole effect, and pressure shift. Change in wave-length from the centre of the arc to the pole, or by pressure, is most likely to occur with lines which are broad even in the centre of the arc. The interferometer measurements were found to be comparatively free from pole effect. In general, the faint lines and those of moderate intensity are sharper than the strong ones, but the width of the average line, expressed as a proportion of the wave-length, appears to be constant throughout the spectrum.

THE RELATION BETWEEN COMPOSITION AND DENSITY OF AQUEOUS SOLUTIONS OF COPPER SULPHATE AND SULPHURIC ACID.*

By H. D. Holler and E. L. Peffer.

[ABSTRACT.]

SOLUTIONS of copper sulphate and sulphuric acid varying in concentration from 0 to 20 per cent. of each solute were made up and their densities determined at 25° and 40° C. The solutions were made of a known composition by weight in order to avoid the influence of temperature in their preparation. The density measurements were made by weighing in the sample under investigation a sinker of known mass and volume.

The effect upon the density by the addition of definite amounts of copper sulphate to sulphuric acid solutions and of definite amounts of sulphuric acid to copper sulphate solutions is shown graphically.

The close agreement in the density of solutions of the same total concentration is also shown by the same curves.

The density of copper sulphate-sulphuric acid solutions, within the range studied, is approximately a linear function of the concentration.

A method for determining and adjusting the composition of copper sulphate-sulphuric acid solutions for electrolytic copper baths may be devised from the results of this investigation.

* Scientific Paper No. 275.

NOTES ON THE BAUMÉ SCALES IN USE IN THE UNITED STATES.*

By H. W. Bearce.

[ABSTRACT.]

The paper gives the origin, history, and present status of the Baumé scales in use in the United States, with special reference to the scale used in the petroleum oil industry. It is intended to correct certain misinformation in regard to the basis and time of adoption of the American Standard Baumé Scale for liquids lighter than water. It is of interest in connection with the Petroleum Oil Tables recently issued by the Bureau of Standards (Circular No. 57).

STANDARDIZATION OF AUTOMOBILE TIRE FABRIC TESTING.†

By W. S. Lewis and C. J. Cleary.

[ABSTRACT.]

This work was undertaken with the view to standardizing the more important methods of tests made upon 17¼-ounce cotton tire fabric. There was found little or no uniformity in the methods of testing employed by the various mills, and this had given rise to confusion in the interpretation of results of tests. In order to assist in the betterment of this condition, the Bureau, in coöperation with fabric and tire manufacturers, undertook to determine the methods of test most suitable for these fabrics.

The chief causes of variation in test results are due to different tensile strength testing machines, dimensions of test specimens, moisture content of specimen at time of test, method of sampling, and lack of uniformity in the material. Several long series of comparative tests were made to determine which of the several proposed methods for ascertaining each particular physical property of the fabric would give the most consistent and reliable results.

* Scientific Paper No. 276.
† Technological Paper No. 68.

TENSILE STRENGTH DETERMINATIONS UPON DIFFERENT TESTING MACHINES.

This investigation was undertaken to ascertain what differences in the results of tensile strength tests are obtained with testing machines commonly used by the trade. Tests were made at four mills employing different machines, and check tests were made at the Bureau of Standards. Tensile strength test specimens were so cut from the fabric and prepared that the variation in the material was reduced to a minimum. The differences thus found between results obtained from tests at the Bureau of Standards and the mills were large in most instances. An extreme case was that of one machine which gave results about 40 pounds too high upon fabric having a tensile strength of about 225 pounds.

DIMENSION OF TENSILE STRENGTH TEST SPECIMENS.

Five forms of test specimens were found in common use in the testing laboratories, but of these only three were studied, because they were more generally employed and seemed the most practicable. These three different dimensions of test specimens constituted one-inch-wide strips, two-inch-wide strips, and the so-called grab test. In the strip method pieces are cut slightly wider than one and two inches, depending upon the width desired, then ravelling down to one or two inches respectively.

The grab test differs in that the cloth is not cut and the test is made by placing the fabric (intact) between jaws of testing machine which are made one, two, three, or more inches wide.

The results of more than 2000 tests show that the one-inch strip method is fully as satisfactory, as regards accuracy and reliability, as the others. For several reasons, mentioned in the paper, the one-inch method is more desirable, and this dimension has been adopted for one year by many of the large manufacturers and consumers of this fabric.

MOISTURE CONTENT OF FABRIC AND ITS INFLUENCE UPON THE WEIGHT AND TENSILE STRENGTH.

The quantity of uncombined water present in the cotton fibre has a marked influence upon the weight and tensile strength. From preliminary tensile strength tests the results have shown

that for each 1 per cent. of moisture content, upon the basis of 100 parts dry material, there is an increase of tensile strength of approximately 7 per cent. This difference would mean an increase of 80 pounds in tensile strength of a 17¼-ounce tire fabric if the moisture content were increased from 3.5 per cent. to 8.5 per cent. or 5 per cent. Under this same 5 per cent. added moisture a 17¼-ounce tire fabric would increase 25 pounds in weight in a 500-yard roll. It is therefore necessary to adopt standard conditions in order to make comparable tests. Two methods were studied; *i.e.*, (1) drying the fabric samples in such a way as to eliminate the question of moisture entirely, or (2) exposing the test samples to a standard atmosphere until they have absorbed all the moisture they will absorb and the samples have come into equilibrium with the atmosphere.

It was found that greater uniformity between individual tests was obtained by drying the test specimens and eliminating all water except that of chemical composition.

METHOD OF SAMPLING FOR DETERMINING WARP TENSILE STRENGTH.

Tire fabric is usually made about 60 inches wide and shipped in rolls varying from 100 to 1000 yards in length.

A common mill method of procedure is to cut from the roll a piece of fabric 10 inches long and the full width (60 inches), then from the centre three test pieces from the warp direction are selected for tensile strength tests. These test pieces were never more than 3 inches wide, therefore only 6 to 9 inches out of the 60-inch width were tested, *i.e.*, leaving more than 50 inches untested.

The Bureau and others made exhaustive tests upon test pieces cut at various places across the full width. A compilation of these results shows little differences in tensile strength at any place within 2 inches of the selvages. By taking test pieces well distributed from selvage to selvage the weakest and strongest parts of the fabric would be found; therefore the Bureau recommends that the average of the results of such tests should be taken as more fairly representative of the strength of the fabric.

THE EFFECT OF CERTAIN PIGMENTS ON LINSEED OIL.*

By E. W. Boughton.

[ABSTRACT.]

THE constants, including yield of ash, or raw linseed oil mixed with white lead in paste form, showed no material change in 25 months. Storage in partially-filled containers for one year of raw linseed oil mixed with white lead and with white zinc (in the proportions of paint ready for use) and exposure to air of films of such mixtures resulted in sufficient combination of oil and pigment to cause the extracted oils to yield amounts of ash that were much larger than those obtained from the oils used to prepare the mixtures. Exposure to air of films of these pigments mixed with boiled linseed oil also caused appreciable combination of oil and pigment. When white lead and white zinc were mixed with linseed oil fatty acids considerable combination of pigment and fatty acids occurred. The amount of fatty anhydride combined as zinc soap was nearly four times as great as that combined as lead soap, the calculations being based on the amounts of ash yielded by the ether extracts of the pigment—fatty acids mixtures and the ratios of the combining weights of zinc oxide and lead monoxide. The results as a whole indicate that white zinc combines with the free fatty acids of linseed oil more readily than does white lead. Of the three pigments, white lead, white zinc, and China clay, the former showed the greatest accelerative effect on the oxidation of raw linseed oil in films composed of pigment and oil, while China clay had the least accelerative effect. When a mixture of raw linseed oil and China clay was kept in a partially-filled container for one year the constants of the oil were materially changed, while raw linseed oil with chrome yellow and with zinc yellow under the same conditions showed practically no change. In drying films, however, the accelerative effects of the two yellow pigments on the oxidation of the oil were much greater than that of China clay.

THE TESTING OF GLASS VOLUMETRIC APPARATUS, 8th EDITION, REVISED.†

THE circular contains specifications for glass volumetric apparatus, including burettes, pipettes, flasks, cylindrical graduates.

* Technologic Paper No. 71.

† Circular No. 9.

specific gravity flasks for Portland cement, Babcock test bottles, etc.

The principal change in the new edition is the adoption and recommendation of the abbreviation "ml" instead of "cc." for designating the millilitre, the metric unit of volume employed in all volumetric work.

Specifications have been added for several new graduates for weights and measures inspectors.

STANDARD DENSITY AND VOLUMETRIC TABLES, 5th EDITION, REVISED.*

The circular contains tables for use in measurements of density and volume of such liquids as water, alcohol, sugar solutions, petroleum oils, etc., and special tables for use in the calibration of glass volumetric apparatus and hydrometers.

In the new edition the tables have been rearranged and several new tables added.

INVAR AND RELATED NICKEL STEELS.†

[ABSTRACT.]

Circular No. 58 of the Bureau of Standards describes in considerable detail the physical properties, microstructure, and constitution of the nickel steels, with particular reference to the alloy of zero expansion known as "Invar." The circular is a compilation of data from many sources, the pioneer work of Hopkinson, Osmond, Dumas, Guillaume, and Guillet being particularly emphasized, and rather full accounts being given also of the more recent investigations carried out by Hegg, Tammann, Chevenard, and many others.

A large portion of the text deals with the thermal expansion and constancy of invar and its characteristics as a length standard in bars, wires, and tapes. The text is accompanied by numerous tables and figures illustrating the various properties not only of invar but of the nickel steels in general. There are chapters on the magnetic, electrical, mechanical, and thermal properties, applications and sources of supply, and brief accounts of microstructure and constitution.

* Circular No. 19.
† Circular No. 58.

Experiments with Filaments Heated Electrically in Volatile Liquids. S. W. J. SMITH. (*Proceedings of The Physical Society of London,* vol. xxviii, part i, December 15, 1915.)—These experiments originated in the use as a resistance in a 200-volt circuit of an ordinary 100-volt incandescent lamp filled with paraffin oil. It was found most satisfactory, both as being able to absorb more power than with a vacuum and also to withstand momentary overload much better. When the current is flowing there is naturally a strong current of hot oil up the legs of the filament. When sufficient current is used, bubbles form on the filament, but these, instead of rising to the surface, run down the legs against both gravity and the upward current of hot oil and come off at the bottom.

Further investigation disclosed another more striking phenomenon. Placing the 100-volt lamp in a 100-volt circuit in series with a variable resistance (conveniently a water-trough), it was found possible, by momentarily cutting out most of the resistance, to obtain a single bubble along the wire. This bubble, instead of escaping at either terminal, travels backward and forward between the two, " looping the loops " of the filament in a fascinating way during every journey.

The peculiarities of this phenomenon, which can be obtained with either direct or alternating supply, have been analyzed by examining the size and motion of the bubble under various conditions and also by using filaments of different materials and liquids of different boiling-points. It is shown from the experiments that a rapid fall of temperature from the wire through the liquid, in the region through which the bubble moves, is an essential condition of the phenomenon, and, also from theoretical considerations, how this condition can be used to explain why the bubble moves in the manner described.

Vibration of a Turbo-generator by Resonance. J. VICENAIF. (*La Revue Electrique,* vol. xxiv, No. 283, October 1, 1915.)—Every structure has a natural period of vibration whose rate in general terms is dependent upon its elastic properties and its mass. Subjected to periodic impulses of the same rate, the structure will vibrate in unison with them, resulting in objectionable and, when the elastic conditions are favorable, dangerous oscillations. A case of this kind is reported in the Russian periodical, *Vestnik Ingenerov.* A turbo-generator attached to a structural steel floor supported by steel columns, when running at its normal speed of 3000 revolutions per minute, caused such serious oscillations of the structure that it was found impossible to operate the unit. A remedy was found in elastically supporting the bearings of the rotating members. So supported, the rotating parts have a period of natural vibration which is no longer coincident with the rotational impulses, and the action of the spring supports reduces the magnitude of the impulses received by the structure as a whole to such an extent that their effects are extinguished by the damping properties of the structure.

NOTES FROM NELA RESEARCH LABORATORY.*

REFRACTION AND ACCOMMODATION IN THE DOG'S EYE: A CORRECTION.

By H. M. Johnson.

In a note which recently appeared in this journal [1] the writer asserted, on the authority of Freytag, that the refractive indices of the lens and fluid media of the dog's eye are practically identical, and that several other species of infra-primate mammals suffer under the same condition. If this assertion were true, its significance would be very great indeed, since in such case the animals concerning which it is made could not change the focal distance of the eye by any mechanism of accommodation which mammals are known to possess.

At the time my note was published, I had been unable to procure a copy of Freytag's original article.[2] My assertion was based on my acceptance of a reference made by an American compiler to Freytag's work, in which a series of values were presented in tabular form as Freytag's. A comparison of the latter with the original article, which I have since obtained, shows that Freytag was incorrectly quoted by his reviewer, although the error is clearly unintentional. Freytag actually gives as mean values of the refractive indices in young and old dogs: for the aqueous humor, 1.3349; for the vitreous humor, 1.33483; and for the lens, values ranging between 1.4498 and 1.4666, depending on age. These differences are greater than those obtaining between the refractive indices of the lens and fluid media in the human eye, and are comparable with the differences found in the other mammals which Freytag studied.

In the individual dog which I studied no clear evidence of

* Communicated by the Director.

[1] "Visual Pattern-discrimination in the Vertebrates—V. A Demonstration of the Dog's Deficiency in Detail Vision," in "Notes from the Nela Research Laboratory," Journal of The Franklin Institute, December, 1915.

[2] Freytag, G.: "Die Brechungsindices der Linse und der flüssigen Augenmedien bei der Katze und beim Kaninchen," *Arch. f. vergl. Ophthalmologie*, vol. i, 1909–10.

accommodation could be obtained. Momentary fluctuations in refraction varying from 0.25 to 0.75 D occasionally appeared during a prolonged examination. These may have been caused by accommodation, but they are as readily explainable on other assumptions. The facts are quite consistent with the results obtained by Boden,[3] who refracted the eyes of 100 dogs both before and during mydriasis.

These individual dogs apparently make little or no use of their mechanism of accommodation. If this is generally true of dogs as a class, it would seem that the defect is retinal rather than in the accommodatory apparatus itself. If it may be assumed that the stimulus to accommodation is indistinctness of the retinal image, it is evident that an animal whose retina is relatively insensitive to detail would have relatively slight stimulus to accommodation.

As regards the conclusions which I drew from the experiments reported in the above note, I still feel quite safe in applying them to the dog. They cannot properly be extended to cover other infra-primate mammals, however, until more is known about the extent and range of accommodation in the latter.

A FORM OF THE HOLBORN-KURLBAUM OPTICAL PYROMETER ADAPTED TO A WIDE RANGE OF LABORATORY USES.

By W. E. Forsythe.

THERE has been constructed for use in Nela Research Laboratory an optical pyrometer that is thought to have some advantages over existing forms.

In this pyrometer are used tungsten pyrometer lamp filaments, and, as these are quite small (diameters 0.0015 to 0.0025 inch), an eye-piece with quite large magnifying power had to be employed. The mounting of the pyrometer lamp is so constructed that all possible adjustments, such as raising and lowering, moving the filament across the field of view, turning and tipping the bulb, can be easily obtained. The holder of the pyrometer lamp is so arranged that it can be rotated in a collar

[3] Boden, Rudolf: "Ueber den Refraktionszustand des Hundeauges," *Arch. f. vergl. Ophthalmologie*, vol. i, 1909–10.

in such a manner that the pyrometer filament can be set at any desired angle with respect to a lamp filament or other source that is being studied. The objective lens is fixed so that, with a very short rack for focussing, adjustments from a magnification of two times down to a focus for parallel light can be easily obtained.

Limiting diaphragms are placed between the objective lens and the pyrometer filament and also between the pyrometer filament and the eye-piece. An opening is left just in front of the lamp-holder for the purpose of inserting rotating sector disks, as it has been shown that when rotating sector disks are used they should be placed as near the pyrometer lamp as possible.

The support for the pyrometer permits of all possible adjustments, such as turning, tipping, raising, and lowering. In the completed description to be published in the *Astrophysical Journal* are given some reasons for using tungsten pyrometer filaments.

A FILTER FOR SPECTROPHOTOGRAPHY.

By M. Luckiesh.

IN a great deal of spectrophotography it would be desirable to have available a photographic emulsion of uniform spectral sensibility and an illuminant having a uniform spectral distribution of energy. Such ideal emulsions and illuminants are not available, therefore it is customary to resort to colored filters to obtain the same final result. Templates might also be used. However, it is a long and tedious task to make an accurate filter for a given combination of photographic emulsion and illuminant. The writer has used a simple scheme for a number of years which involves what might be termed a "spectrophotographic filter." A photographic plate (of the kind to be used in the investigation) is placed in its ordinary position in a spectrograph, with the exception that the sensitive film is placed away from the prism or grating. Several spectrograms of the illuminant to be used are made on the plate, varying in exposure. In general these negatives should be of rather light density. After developing, fixing, and drying the plate, it is placed in the plate-holder in the original position and another plate is placed on top of it, the sensitive films being in contact. Spectro-

grams of the illuminant made through the negatives on the first plate will show quite uniform densities throughout practically the whole spectral range of chief sensibility. When the best exposure is found for the original plate a convenient "filter" can be made by exposing an entire plate by moving the plate-holder uniformly along the guides. After developing, fixing, and drying this negative, a wave-length scale may be ruled upon it, unless it has been previously photographed upon the plate. Obviously a "filter" must be made with the same kind of plate as that to be used with it. Successful results have been obtained with both grating and prism spectrographs. The scheme corrects for the dispersion of the prism for the latter instruments.

In the table results are presented which represent the transmission of the final spectrogram in different parts of the spectrum. Column F represents the transmission (related very simply to photographic effect) of the filter. This also gives an idea of the extreme non-uniform sensibility of available panchromatic plates. Column S represents the final effect, showing that this simple method very largely compensates for the non-uniform sensibility of the plates and the non-uniform spectral distribution of energy in the illuminant. The former, however, is more serious in general. Uses of this simple scheme are obvious.

Wave-length μ	Wratten and Wainwright panchromatic plate		Cramer spectrum plate	
	F	S	F	S
0.375	0.982	0.597	1.00	0.79
0.396	0.64	0.314	0.900	0.282
0.416	0.353	0.234	0.545	0.172
0.436	0.221	0.231	0.356	0.196
0.457	0.158	0.222	0.261	0.206
0.478	0.180	0.190	0.358	0.200
0.498	0.314	0.187	0.802	0.238
0.519	0.414	0.172	0.757	0.179
0.540	0.328	0.172	0.52	0.144
0.561	0.345	0.177	0.320	0.157
0.582	0.291	0.168	0.402	0.172
0.602	0.405	0.142	0.435	0.202
0.623	0.303	0.193	0.451	0.172
0.643	0.254	0.200	0.395	0.174
0.664	0.64	0.161	0.652	0.213
0.675	——	0.342	——	——
0.684	——	——	0.930	0.574

THE LAWS OF VISUAL MINUTHESIS:* THE THRESHOLD PRE-EXPOSURE TIME AND THE EQUILIBRIUM TIME FOR A PROJECTED NEGATIVE AFTER-IMAGE.[1]

By Leonard T. Troland.

THE following is a preliminary report of one of a series of investigations being carried out to determine the laws which govern the decay of a semicircular after-image, variously produced, but always projected on a circular, luminous field of its own diameter, so as to fill one-half of this field.

In the present experiment four different ranges of the spectrum were employed, and the brightness of the uniform stimulus fields in which they were presented were made equal, by the flicker photometer, to 31.6 candles per square metre. The stimulus field was provided with a central fixation point, always visible, had an angular diameter of 3.38 degrees, and was viewed through an artificial pupil—of 2.36 mm. diameter—against a dark background. Five minutes' dark adaptation was allowed before beginning a set of measurements. The results given are for the writer's right eye.

The relation selected for study was $t_q = f(t_p)$, where t_p is the preliminary time of exposure of the eye to the first semicircle, and t_q is the time from the moment of exposure of the second semicircle until the minuthetic (or "fatigue") contrast disappears. The three cases tested were: $t_p = 300$ seconds (which is practically equivalent to $t_p = \infty$), $t_p = 30$ seconds, and $t_q = 0$.

The last case involves a determination of the "threshold preëxposure time," or the minimum time which will produce a noticeable minuthesis under the given conditions. This was attempted by the method of "constant stimuli." Four hundred observations were made on each color, the right- and left-hand sides of the field being presented first, an equal number of times. If, at the first instant of exposure of the second half of the field, the preëxposed half looked darker than the other, the contrast

* The writer has proposed the term *minuthesis* to designate, in place of the inappropriate word "fatigue," any decrease in the sensitivity of a sense organ, due to stimulation.

[1] To be published in the *Journal of Experimental Psychology*.

was called negative; if brighter, it was called positive. The results follow:

Color	Wave-length, in $\mu\mu$	t_p in σ*	Number of trials					
			Right first			Left first		
			Positive	Equal	Negative	Positive	Equal	Negative
Red	666.5 – 689.3	35.0	1	27	22	2	30	18
		57.2	1	15	34	0	18	32
		78.6	0	6	44	3	7	40
		100.2	0	2	48	0	1	49
Yellow	574.2 – 587.4	35.0	9	19	22	2	13	35
		57.2	7	15	28	0	14	36
		78.6	4	12	34	1	8	41
		100.2	0	6	44	1	3	46
Green	516.0 – 525.4	35.0	12	23	15	7	28	15
		57.2	10	23	17	3	21	26
		78.6	12	13	25	4	10	36
		100.2	6	11	33	0	8	42
Blue	445.7 – 451.0	35.0	17	20	13	1	23	26
		57.2	14	16	20	0	11	39
		78.6	11	15	24	1	10	39
		100.2	0	5	45	1	1	48

* σ = 0.001 second.

Calculation of these results, by the traditional method of "right and wrong cases," judgments of negative contrast being regarded as "right," gives the following values for the threshold:

Color	Threshold time		Space error	Corrected threshold
	Right first	Left first		
	σ	σ	σ	σ
Red	52.50	50.35	– 1.08	51.43
	(h = .0944)	(h = .03204)		
Yellow	46.50	– 4.198	– 25.35	21.15
	(h = .01231)	(h = .008115)		
Green	70.15	55.75	– 7.20	62.95
	(h = .01052)	(h = .01684)		
Blue	70.75	30.60	– 20.08	50.68
	(h = .01413)	(h = .01406)		

The large space errors are probably due to a slight lack of uniformity in the stimulus field.

The average values found for t_q, with $t_p = 30$, and $t_p = 300$ seconds, respectively, are given in the following table. Each average represents ten trials.

Color	Right first, seconds	Left first, seconds	Space error, seconds	Corrected value, seconds
	Preëxposure time, t_p, = 30 seconds. Equality time, t_q			
Red	86.2 (A. D. = 2.2)	92.5 (A. D. = 3.0)	3.2	89.4
Yellow	90.6 (A. D. = 2.1)	95.3 (A. D. = 1.6)	2.4	93.0
Green	91.5 (A. D. = 3.1)	93.3 (A. D. = 3.8)	0.9	92.4
Blue	76.5 (A. D. = 1.8)	89.1 (A. D. = 3.8)	6.3	82.8
	Preëxposure time, t_p, = 300 seconds			
Red	156.8 (A. D. = 4.7)	143.9 (A. D. = 2.3)	−6.5	150.4
Yellow	180.0 (A. D. = 6.5)	164.1 (A. D. = 4.5)	−8.0	172.1
Green	162.4 (A. D. = 4.0)	152.4 (A. D. = 3.7)	−5.0	167.4
Blue	147.2 (A. D. = 3.8)	146.3 (A. D. = 4.3)	−0.5	146.8

Since t_q, for $t_p = 300$, represents closely equilibrium conditions of sensitivity, it may be called the "equilibrium time."

This work is now being repeated with other subjects and under improved conditions. The results are ultimately intended to test a theoretical equation for $t_q = f(t_p)$, deduced from assumptions with regard to the chemical nature of the retinal process.

Research on the Corrosion Resistance of Copper Steel. D. M. BUCK and J. O. HANDY. (*The Journal of Industrial and Engineering Chemistry*, vol. 8, No. 3, March, 1916.)—Sheet steel and iron-containing copper show greatly-increased corrosion resistance when exposed to atmospheric conditions. The most effective amount of copper to be used for this purpose is approximately 0.25 per cent. Smaller amounts of copper down to as little as 0.04 per cent. have a considerable influence in lessening corrosion, but the results are not so good as with the higher amount. Previous investigation has indicated that 0.15 per cent. copper is in nearly all cases as efficient as 0.25 per cent. Higher amounts of copper up to 2 per cent. give little or no added benefit. Copper is as necessary in the so-called "pure irons" to insure corrosion resistance as it is in normal open-hearth and Bessemer steels.

Pasteurized Milk. ANON. (*Scientific American Supplement*, vol. lxxxi, No. 2097, March 11, 1916.)—That there is no valid objection to pasteurization when properly performed, and that the process makes safer even the most carefully handled and inspected milk, is the conclusion of a new professional paper of the United States Department of Agriculture, in which are set forth the most recent conclusions of scientists in regard to this matter. According to this paper, it seems probable that within the next two years a large proportion of the milk supply in the large cities will be pasteurized. Before the value of pasteurization as a hygienic measure was as well recognized as it is to-day, it was practised in secret by a number of milk dealers as a means of preserving milk and preventing it from souring. Its commercial value in this respect is undoubtedly great, but its chief function is the destruction of disease-producing organisms. Proper pasteurization should destroy about 99 per cent. of all the bacteria in milk, although when the bacterial count in raw milk is low the reduction may be somewhat smaller. The efficiency of the process, it is pointed out, cannot be based on the percentage, but rather on the character of the bacteria destroyed.

The kinds of bacteria that remain alive after pasteurization depend on the temperature to which the milk is heated and the species of bacteria that are in the raw milk. Three processes of pasteurization, known respectively as the flash process, the holder process, and pasteurization in the bottle, are practised in this country. In the flash process the milk is raised quickly to a temperature of 160° F. or more, held there for 30 seconds to a minute, and then cooled quickly. In the holder process the milk is heated to a temperature of 140° to 150° F. and held there for half an hour. When pasteurization in bottles is practised, the raw milk is put into bottles with watertight seal caps, which are immersed in hot water and held for 20 to 30 minutes at a temperature of 145° F. In this way the milk is not subjected to any danger of reinfection. On the other hand, the seal caps must be absolutely tight, and this involves increased cost. In general it may be said that the holder process is coming into greater favor than either of the others. This process permits of the use of lower temperatures, which for various reasons is highly desirable. Another method of pasteurization, or rather a modification of the present holder process, suggested by the Department investigators, is that of bottling hot pasteurized milk. The process consists of pasteurizing the milk by the holder process at 145° F. for 30 minutes, then bottling it while hot in hot bottles steamed for two minutes immediately before filling. After filling, the bottles are capped, and may be cooled by any of the systems in which the caps are protected. The bottles are sprayed with water or cooled by forced-air circulation. The bulletin concludes that pasteurization by the holder process is to-day the most effective means of obtaining safe milk.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 15, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 15.

A report on the condition of the work of the Committee on Science and the Arts was presented.

The President announced that the presentation of certain medals recently recommended for award by the Committee on Science and the Arts was in order and recognized Mr. Charles E. Bonine, chairman of the committee, who introduced Mr. Clement F. Street, of New York City, to whom had been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute, for the Street Locomotive Stoker.

The Street is an overfed type of stoker. The coal is brought by a worm conveyor from the tender to a hopper and is elevated from the hopper by an endless chain of buckets to a point near the top of the back head of the boiler. The coal is then directed from this point to three firing points in the back head, and at these points steam jets blow it into the firebox.

Over six hundred Street Stokers are in successful operation.

The President presented the medal and accompanying certificate to Mr. Street, who returned his thanks for the honor conferred upon him.

Mr. Bonine was again recognized and introduced Mr. Frederick A. Hart, of New York City, to whom had been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute, for his inventions embodied in John Underwood and Company's Combined Typewriting and Calculating Machine.

The elements of this machine are a standard Underwood Typewriter and a motor-driven adding and subtracting machine. The adding machine is so constructed as to be controlled by the typewriter, which is superimposed upon it so that the numbers written upon the typewriter may be transferred to the adding machine.

The President presented the medal and accompanying certificate to Mr. Hart, who expressed his thanks for the recognition of the inventions of himself and his co-workers.

Mr. Bonine was again recognized by the President and introduced Mr. C. D. Rice, a representative of John Underwood and Company, of New York City, to receive the Edward Longstreth Medal of Merit, which was awarded his company for developing their Combined Typewriting and Calculating Machine to a successful commercial form.

The President presented the medal to Mr. Rice, who thanked the Institute for the award made to the company.

Mr. Bonine was again recognized and introduced Mr. Benjamin G. Waggner, of Philadelphia, Pa., to whom the Institute had awarded its Edward Longstreth Medal of Merit for improvements in Prepayment Attachments for Gas Meters. This attachment is a device designed to provide simple and accurate means for the delivery of a predetermined volume of gas through a meter after the purchase price has been deposited in the cash-box and to insure the positive closing of the prepayment valve at the proper time.

The President presented the medal to Mr. Waggner, who thanked the Institute for the honor it had conferred upon him.

Mr. Hans Hanson, of Hartford, Conn., was also awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute, for his inventions embodied in John Underwood and Company's Combined Typewriting and Calculating Machine, but was unable to attend the meeting. He expressed his appreciation by letter for the City's and Institute's action.

Arthur L. Day, Ph.D., Sc.D., Director, Geophysical Laboratory of the Carnegie Institution of Washington, then addressed the meeting on "Volcanic Eruptions." The speaker gave a *résumé* of the recent investigations made to determine the character of the chemical reactions which take place in volcanic activity and which are undoubtedly one of the important causes of such disturbances. The results obtained are based on studies made of the European volcanoes: Vesuvius, Etna, Stromboli, and Vulcano, as well as Lassen Peak in northern California and Kilauea in the Hawaiian Islands. Numerous colored lantern views were shown.

After a brief discussion the unanimous thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

[CORRESPONDENCE.]

To the President and Committee on Science and the Arts of The Franklin Institute of the State of Pennsylvania:

GENTLEMEN: Mr. R. B. Owens, Secretary of your Institute, has informed me that the City of Philadelphia, on recommendation of your Committee on Science and the Arts, has awarded me the John Scott Legacy Medal and Premium, and inquired if it would be convenient for me to be present at your next meeting on the evening of Wednesday, March 15, to receive the same in person.

In acknowledging receipt of the letter from Mr. Owens, I stated that, on account of serious deafness, I considered it wiser to remain at home, because I would be unable to hear any remarks usually made on such occasions.

Recognizing fully the significance and honor of being granted this award, I admit I felt some pangs of regret in denying myself the accorded privilege

of being personally present to receive it, but you readily understand that, under the conditions stated, the pleasure of being present might easily be more than counterbalanced by embarrassment, and for that reason I take this method of expressing my most heartfelt appreciation of the honor bestowed on me by the granting of this award, and if the work I have done, which forms the basis of this recognition, is even in a very small degree of real assistance in human activities and progress, I shall always feel that I have done something that should be a source of satisfaction to me.

As awards have also been granted to others in connection with my invention, I merely wish to express my personal feelings in regard to the assistance given me in the development of my original ideas. Without financial aid I could not have gone very far, and a great deal of credit is due to Mr. John T. Underwood, who undertook to furnish the necessary capital, an undertaking much more costly than I think he bargained for, and much more so than I had any idea would be the case; and, as my dealings from the first were with him personally, I am well qualified to speak of him in connection with this work. I wish to say that during more than thirteen years that have passed since I first met him there has never been the slightest misunderstanding between us that I am aware of, and that his word has always been as good as his bond, and I consider it a most remarkable feature that he always seemed to remember what either one of us had said, even though years had passed by, when one considers that he is a very busy man and engaged in many varied activities requiring his serious attention.

Considering that he has borne, personally, until very recently, the very great expense, and that so many years were required to develop this machine, he has shown a great deal of pluck and persistence, and I hope he will be rewarded some time for the faith he has displayed. Many another man, or set of men, might have become discouraged long before the desired results were attained.

While I am considered the originator of the more essential features of this invention, I did not have the technical knowledge required to put my ideas in the best mechanical form for manufacturing purposes, and it was our good fortune to secure the services of Mr. Frederick A. Hart, who took hold of that end of the proposition, and who is also the possessor of a great deal of inventive skill, which has been used with good effect to improve upon my ideas, which left much to be desired, particularly in regard to convenience and appearance. It has taken a vast amount of work to produce the machine as it now stands, and this work has been under Mr. Hart's supervision, and he is entitled to much credit for having worked hard and faithfully to produce a machine that would be satisfactory to the purchaser and user thereof. He did not work merely for the compensation he received, but to produce desired results, and there is a vast difference between these two objectives, and I am glad to know that he has been granted the same award as myself, as his work deserves fully as much recognition as mine, and, of the two, he has had much more to look after than I.

Mr. Rice has had something to do with the manufacturing of the invention, on account of his position as superintendent of the Underwood Typewriter Factory, but what I particularly want to refer to here is the fact that he was

the first, outside of those who made the original model, to see the interior mechanism and pass an opinion thereon, on which opinion Mr. Underwood based his decision to take hold of the invention. I passed a few anxious days waiting for the outcome of his report to Mr. Underwood, which I soon learned was favorable, and I felt a great burden lifted from my mind. I sincerely hope that final results have been satisfactory enough to Mr. Rice to prove that his judgment of the possibilities of the invention was not misplaced, and what might have happened if his opinion had been unfavorable no one knows, but I feel sure that it would, in all probability, have been impossible for me to have found as good financial support and otherwise congenial associates in this venture as it was my good fortune to find almost without effort.

The invention, as now produced, is the product of many minds, and I am glad to acknowledge that as a fact, and willing to give credit to every one who has helped to make it what it is to-day.

It was my good fortune to come along with my efforts at just about the right time. I knew nothing of what others had done in this particular line of endeavor, but nothing could have been successfully done very long before I started on this work in 1896. The typewriter was fairly well established at that time, and the adding machine was being forced to the front, against the opinion of many who considered it impossible for a machine to do what had been considered the work of the human mind or brain, but the machine won out, and business men were getting their minds prepared for the combined typewriter and computing machine, which will soon be a necessity in every business establishment of even comparatively small size.

The path of the inventor is more often full of thorns than of roses, and many a good invention and inventor falls by the wayside for lack of appreciation and the necessary means to develop it and present it to the world and to defend his rights in regard to patents, which latter is a costly process—so costly and full of pitfalls that a poor inventor stands a very small chance of obtaining his rights if he has an adversary with plenty of resources to hire the best legal talent obtainable.

Had I known the difficulties ahead of me in getting my patents, I would never have started, but it was a case of "when it is bliss to be ignorant, it is folly to be wise." I have been a party to eight or nine interference proceedings, and lost only one, which was of minor importance.

In conclusion, I wish to pay a word of tribute to the men who, by their generosity, have made possible the awards of medals, premiums, and diplomas to those who are considered to merit the same, and, in my own case, more particularly to John Scott, and also wish to express my sincere thanks to The Franklin Institute and its Committee on Science and the Arts for recommending my invention for the award of this medal and premium, and to assure them that I fully appreciate the honor of receiving this award.

Very respectfully,

(Signed) H. HANSON.

HARTFORD, CONNECTICUT, March 13, 1916.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 1, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 1, 1916.

MR. J. A. P. CRISFIELD, *Chairman pro tem.*

The following reports were presented for final action:

No. 2654.—Circle Drawing Attachment for Microscopes. Certificate of Merit to Philip Atlee Sheaff, of Philadelphia, Pa., adopted.

No. 2655.—Prepayment Attachment for Gas Meters. Edward Longstreth Medal of Merit to Benjamin G. Waggner, of Philadelphia, Pa., adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, February 24, 1916, at 8 P.M. Mr. Louis E. Levy occupied the chair. The minutes of the previous meeting were read and approved.

Mr. William D. Uhler, Chief Engineer, State Highway Department, Harrisburg, Pa., delivered an illustrated lecture, entitled "Highway Problems of the State of Pennsylvania."

Mr. Uhler discussed the difficulties in taking care of the elaborate system of highways of the commonwealth. He pointed out the mistakes which were made when the roads were originally laid out, and showed how a more comprehensive system of main-travelled thoroughfares could have been established with benefit to the state. The general and specific maintenance of the roads was discussed; the methods of caring for the various types of roads found throughout the state were described, and it was pointed out that revenues sufficient to maintain these roads in proper condition must be provided before permanent construction can be undertaken.

After an interesting discussion a vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 2, 1916, at 8 o'clock P.M., with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

George A. Rankin, A.B., of the Geophysical Laboratory of the Carnegie Institution of Washington, Washington, D. C., presented a communication on

"Portland Cement." The history of Portland cement was traced. The procedure used in the manufacture of American Portland cement was outlined, as were the reactions which occur in the kiln and the nature of the product obtained. The compounds which are formed on ignition of mixtures of calcium, aluminum, and silicon oxides were described, and the technic of fusion and of analysis of the product was outlined. The proportions in which these compounds occur in pure and commercial cements, and their relation to the "setting" of the cement, were discussed. The procedure to be followed in a further systematic study of the best composition of cements for various purposes was pointed out. The lecture was illustrated with lantern slides.

The paper was discussed by Messrs. Lesley, Humphrey and others. A vote of thanks was tendered Mr. Rankin, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 9, 1916, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

George C. Whipple, S.B., Gordon McKay Professor of Sanitary Engineering, Harvard University, Cambridge, Mass., member of the firm of Hazen, Whipple & Fuller, consulting engineers, New York City, delivered a lecture, entitled "The Element of Chance in Sanitation," dealing with the applications of the laws of probability to certain problems of vital statistics, epidemiology, water pollution, and water purification. With the help of lantern slides and specially ruled cross-section paper, Professor Whipple demonstrated the element of chance in making bacteriological tests of water supply, milk, etc., and also explained how this cross-section paper was useful in approximating the maximum rainfall that might be expected in any section where records had been kept of the rainfall and run-off for a number of years, and how such results could be used in determining the size of spillways for dams.

After a brief discussion, a vote of thanks was extended to Professor Whipple.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 8, 1916.)

RESIDENT.

MR. HENRY BUTLER ALLEN, metallurgical engineer, Henry Disston & Sons, Tacony, Philadelphia, Pa.

MR. CHARLES W. ASBURY, vice-president, Enterprise Manufacturing Company of Pennsylvania, Third and Dauphin Streets, Philadelphia, Pa.

MR. CHARLES MILLER BIDDLE, JR., first vice-president, Supplee-Biddle Hardware Company, 517 Commerce Street, Philadelphia, Pa.
MR. CHARLES L. CONN, president, Giant Portland Cement Company, Pennsylvania Building, Philadelphia, Pa.
MR. WILLIAM H. DONNER, Morris Building, Philadelphia, Pa.
MR. FRANK B. FOSTER, manufacturer, The Congoleum Company, Morris Building, Philadelphia, Pa.
MR. R. H. NORTH, North Bros. Manufacturing Company, Lehigh Avenue and American Street, Philadelphia, Pa.

NON-RESIDENT.

MR. A. F. HUSTON, president, Lukens Iron and Steel Company, Coatesville, Pa.
MR. CHARLES L. HUSTON, vice-president and manager, Lukens Iron and Steel Company, Coatesville, Pa.
MR. FRANK P. MILLER, Frank P. Miller Paper Company, East Downingtown, Pa.
MR. GUYON MILLER, president, Downingtown Manufacturing Company, Downingtown, Pa.
MR. GEORGE W. RAMSEY, patent attorney, 700 Tenth Street, Washington, D. C.
MR. WILLIAM H. RIDGWAY, manufacturer and civil engineer, The Craig Ridgway & Son Company, Coatesville, Pa.
MR. L. D. VORCE, chemical engineer, vice-president, Tennessee Copper Company, 2 Rector Street, New York City, N. Y.
MR. WILLIAM H. WALDRON, manufacturer of machinery, New Brunswick, N. J.

CHANGES OF ADDRESS.

MR. RUSSELL L. BRINTON, 1751 North Sixty-first Street, Philadelphia, Pa.
MR. HENRY I. BROWN, care of Miss R. L. Keller, 137 South Fifth Street, Philadelphia, Pa.
MR. LUCIUS P. BROWN, 137 Davis Avenue, West New Brighton, New York City, N. Y.
MR. W. L. GARRELS, Webster Groves, R. R. 5, Box 107, Missouri.
MR. ALEXANDER P. GEST, Cynwyd, Pa.
MR. CLARENCE A. HALL, Cresheim Arms, Mt. Airy, Philadelphia, Pa.
MR. THOMAS SKELTON HARRISON, 1520 Locust Street, Philadelphia, Pa.
MR. FRED. T. HASCHKA, 135 West Seventy-eighth Street, New York City, N. Y.
MR. K. G. MACKENZIE, care of The Texas Company, 17 Battery Place, New York City, N. Y.
PROF. J. A. MOYER, State House, Boston, Mass.
MR. ROBERT S. PERRY, 31 Union Square, West, New York City, N. Y.
DR. SAMUEL P. SADTLER, 210 South Thirteenth Street, Philadelphia, Pa.
MR. H. R. STANFORD, Navy Yard, Philadelphia, Pa.
MR. JAMES H. WAHL, Hollis Court Boulevard, Bellaire, Long Island, N. Y.

NECROLOGY.

Lincoln Godfrey was born in Philadelphia, May 17, 1850, and died February 8, 1916.

He was educated in private schools in his native city and began his business career in the dry-goods house of his father. In 1873 he became a member of the firm of William Simpson Sons & Company, manufacturers of cotton goods. He was director of a number of financial institutions, insurance companies, and important industrial establishments. He became a resident member of The Franklin Institute on February 14, 1912.

Edward Rowland was born in Philadelphia on September 9, 1844, and died in his native city on February 29, 1916.

His membership in The Franklin Institute dates from May, 1878.

Dr. Louis Duncan.
John McIhenny.

LIBRARY NOTES.

PURCHASES.

BALL, SIR ROBERT S.—Reminiscences and Letters. Edited by his son, W. V. Ball. 1915.

BARTON, EDWIN H.—Introduction to the Mechanics of Fluids. 1915.

BEALE, SIR W. PHIPSON.—An Amateur's Introduction to Crystallography. 1915.

DALBY, W. E.—Steam Power. 1915.

Engineering Index.—Annual, vol. 32. 1915.

ENGLER, C., and HOEFER, H. VON.—Das Erdoel, vol. 4. 1916.

HOUSDEN, C. E.—New Time Savers in Hydraulics and Earthworks. 1914.

KINGSBURY, J. E.—The Telephone and Telephone Exchanges. 1915.

MANN, H. LESLIE.—Text-book on Practical Mathematics. 1915.

OELSNER, G. H.—Handbook of Weaves. 1915.

POHL, R., and PRINGSHEIM, P.—Die lichtelektrischen Erscheinungen. 1914.

SCHULTZ, GUSTAV.—Die Chemie des Steinkohlentheers, vol. 1. 1900.

SIBERT, W. L., and STEVENS, J. F.—Construction of the Panama Canal. 1915.

Travelling Engineers' Association.—Proceedings, vols. 1 to 23. 1893 to 1915.

WALKER, MILES.—Specification and Design of Dynamo-electric Machinery. 1915.

WALSH, J. J.—Mining and Mine Ventilation. 1915.

GIFTS.

Accum, Frederick, Practical Treatise on Gas-Light. London, 1818. (From Dr. Walton Clark.)

American Society of Mechanical Engineers, Year Book. New York, 1916. (From the Society.)

Amherst College, Catalogue, 1915–1916. Amherst, Mass., no date. (From the College.)

Association Francaise Pour L'Avancement des Sciences, Compte Rendu de la 43me Session, 1914. Paris, 1915. (From the Association.)

Bausch & Lomb Optical Company, Metro Manual. Rochester, no date. (From the Company.)

Canada Department of Mines, Bulletin No. 12, Investigation of a Reported Discovery of Phosphate in Alberta; Bulletin No. 13, Description of the Laboratories of the Mines Branch of the Department of Mines. Ottawa, 1916. (From the Department.)

Case School of Applied Science, Catalogue, 1915–1916. Cleveland, no date. (From the School.)

Clark University, Register and Twenty-eighth Official Announcement. Worcester, 1916. (From the University.)

Cotter, Arundel, The Authentic History of The United States Steel Corporation. New York, 1916. (From The Moody Magazine and Book Company.)

du Pont, de Nemours, E. I., & Company, High Explosives, Their Manufacture, Storage, Handling and Use, First and Second Sections. Wilmington, no date. (From the Company.)

Hammacher, Schlemmer & Company, Catalogue No. 500, of Hardware, Tools and Supplies. New York, no date. (From the Company.)

Institute of Metals, Journal, vol. xiv, No. 2. London, 1915. (From the Institute.)

International Railroad Master Blacksmiths' Association, Proceedings of the Twenty-third Annual Convention. Lima, 1915. (From the Association.)

Iron and Steel Institute, Journal, vol. xcii, No. 11. London, 1915. (From the Institute.)

Lake Mohonk Conference on the Indian and other Dependent Peoples, Report of the Thirty-third Annual Conference. Lake Mohonk, 1915. (From the Conference.)

Landis Machine Company, Catalogue No. 22, on Threading Machinery. Waynesboro, Pa., no date. (From the Company.)

McClintic-Marshall Company, Portfolio of Construction Work. Pittsburgh, no date. (From the Company.)

Massachusetts Institute of Technology, President's Report. Boston, 1916. (From the Institute.)

Michigan Engineer, vol. 33. Ann Arbor, Mich., 1915. (From the Michigan Engineering Society.)

Michigan State Board of Agriculture, Fifty-fourth Annual Report. Lansing, 1915. (From the Board.)

Missouri Bureau of Geology and Mines, vol. xiii, Second Series, The Stratigraphy of the Pennsylvanian Series in Missouri. Jefferson City, 1915. (From the Bureau.)

Montana Railroad and Public Service Commission, Eighth Annual Report. Helena, 1915. (From the Commission.)

National Electric Light Association, Papers, Reports and Discussions of the Thirty-eighth Convention. New York, 1915. (From the Association.)

New Bedford Water Board, Report, 1915. New Bedford, Mass., 1916. (From the Board.)

New Jersey Foundry and Machine Company, Catalogue No. 88, of Overhead Carrying Devices. New York, no date. (From the Company.)

New Orleans Sewerage and Water Board, Twenty-ninth Semi-annual Report. New Orleans, 1914. (From the Board.)

New South Wales Department of Mines, Report upon the Ardlethan Tinfield. Sydney, 1915. (From the Department.)

New York State Engineer and Surveyor, Annual Report and Supplement, 1914. Albany, 1915. (From the Engineer and Surveyor.)

Norma Company of America, Catalogue No. 105, of Precision Bearings. New York, no date. (From the Company.)

Pennsylvania Department of Mines, Report, Part I, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Railroad, Record of Transportation Lines Owned and Operated by and Associated in Interest with the Pennsylvania Railroad, 1915. Philadelphia, 1916. (From the Company.)

Pennsylvania State Fire Marshal, Annual Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Queensland Department of Mines, Publication No. 227, Index to Publications, Nos. 215 to 226; Publication No. 243, Geology and Mineral Resources of the Stanthorpe, Ballandean and Wallangarra Districts; Publication No. 246, The Einasleigh Freehold Copper Mine, N. Q. Brisbane, 1913 and 1914. (From the Department.)

Reale Istituto d'Incoraggiamento di Napoli, Atti, vol. lxvi. Napoli, 1915. (From the Istituto.)

St. Louis University, Catalogue. St. Louis, 1916. (From the University.)

Statistics of the Dominion of New Zealand, 1914. Wellington, 1915. (From the Government Statistician.)

U. S. National Museum, Report, 1915. Washington, 1916. (From the Museum.)

United States Brewers' Association, Year Book. New York, 1915. (From the Association.)

Vermont Commissioner of Agriculture, Seventh Annual Report. St. Albans, 1915. (From the Commissioner.)

Webster, Warren & Company, The Webster Modulation System. Camden, no date. (From the Company.)

BOOK NOTICES.

ORGANIC CHEMISTRY; or, the Chemistry of the Carbon Compounds, by Victor von Richter. Edited by R. Anschütz and G. Schroeter. Vol. I, Chemistry of the Aliphatic Series. Newly translated and revised from the German edition (after Edgar F. Smith's third American edition), by Percy E. Spielmann, Ph.D., B.Sc., F.I.C., A.R.C.Sc. Philadelphia, P. Blakiston's Son & Co., 1916. 677 pages, contents and index, 8vo. Price, $5.

It is somewhat of an astonishment for an American reviewer to note the phrase "Preface to the First English Edition" when von Richter's book in English form has been for so many years a prominent feature of chemical teaching. On closer examination, however, we find that if "English" is not used in its Pickwickian sense, it is at least employed in the narrow sense of originating in, and being specially adapted for, England. The confusion between the two meanings of this noun gives much trouble,

and it might have been better if the present edition had been termed the "British" edition, especially as the older translation is almost always termed the "American" edition.

It is not necessary to dwell at length on the merits of Richter's book, nor on the merits of the translation. The work is a wonderful presentation of the facts of chemistry, and the rendition into English does great credit to the translator.

The book was printed in England. Paper, type, and press-work are excellent—no small matter in a work so rich in detail and containing so many complicated formulas. Especial praise must be given to the index, which is extensive and clearly printed, features in which possibly the translation much surpasses the German original, for Continental writers have always been weak along that line. The present volume covers half the field of organic chemistry, and will be followed by the chemistry of the cyclic compounds.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Elevators: A Practical Treatise on the Development and Design of Hand, Belt, Steam, Hydraulic, and Electric Elevators, by John H. Jallings, mechanical engineer and elevator expert. 224 pages, illustrations, 8vo. Chicago, American Technical Society, 1915.

North Carolina Geological and Economic Survey: Bulletin No. 24, Loblolly or North Carolina Pine, by W. W. Ashe, Forest Inspector, U. S. Forest Service. Prepared in coöperation with the Forest Service, United States Department of Agriculture. 176 pages, plates, 8vo. Raleigh, State Printers, 1915.

U. S. Bureau of Mines: Bulletin 86, Some Engineering Problems of the Panama Canal in Their Relation to Geology and Topography. Published with the approval of the Governor of the Panama Canal, by Donald F. MacDonald. 88 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1915.

National Association of Wool Manufacturers, Annual Wool Review, 1915. Domestic wool clip, imports of wool and woollens, and other statistical tables. 81 pages, plates, 8vo. Boston, Rockwell & Churchill Press, 1916.

The Colorado Industrial Plan, by John D. Rockefeller, Jr., including a copy of the plan of representation and agreement adopted at the coal and iron mines of the Colorado Fuel and Iron Company, 1916. 95 pages, diagram, 16mo. No place, no date.

U. S. Bureau of Standards: Technologic Paper No. 60, Microstructural Changes Accompanying the Annealing of Cast Bronze (Cu88, Sn10, Zn2). by Henry S. Rawdon, Associate Physicist. 17 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1916.

Address by Dr. Nicholas Murray Butler, President of Columbia University, in the city of New York, to the members of the Union League of Philadelphia, at Founders' Day Celebration, held Saturday evening, November 27, 1915. 14 pages, 12mo. No place, no date.

War Taxes and Waste, speech of Hon. James A. Frear, of Wisconsin, in the House of Representatives, Monday, January 10, 1916. 42 pages, quarto. Reprinted from the *Congressional Record,* January 13, 1916.

CURRENT TOPICS.

Small Incandescent Lamps and Special Illumination Problems. R. P. BURROWS. (*Transactions of the Illuminating Engineering Society*, vol. x, No. 9, December 30, 1915.)—The small incandescent lamps commonly classed as "miniature lamps" are coming to be recognized as contributing a great deal to certain special fields of lighting. Not long ago small lamps were looked upon as playthings and had little or no commercial application. This was due partly to the limitations of the carbon filament in applications where the cost of supplying energy is necessarily high. With the introduction of tungsten as a filament material, and later with the discovery that drawn-wire tungsten could be coiled into concentrated filaments, an extensive field for miniature lamps was opened. Certain problems in the projection of light were materially simplified by the concentrated filament, and, by the introduction of an inert gas into certain types of these small lamps, greatly-increased efficiency was secured.

Following increased demand came a study of the manufacture of these lamps which is gradually taking them out of the class of hand-made products. The difficulties encountered in cutting and mounting by hand a little piece of wire one-third the diameter of a human hair and, say, 10 mm. in length can be more readily appreciated when it is known that 0.5 mm. in the length of filament in certain types means about 5 per cent. difference in voltage. A number of these miniature lamps now have their filaments coiled and cut by very accurate machines, and a few have semi-automatically mounted filaments.

A growing interest in miniature lamps created higher standards in their application to the fields involved. A few years ago almost any lamp which would give light would suffice; now it is essential that the light shall not only be produced economically, but that every detail of the lamp must be specially designed for the purpose. The dry cell hand-lanterns, for instance, first came into the market with demands that all the light possible should be obtained from a single dry cell, without regard to the life of lamp or battery. These lanterns now replace the old oil lantern, and manufacturers are requiring that the battery and lamp shall receive fully as much consideration as the light produced.

Scrap Cutting Machine. R. G. SKERRETT. (*The Iron Age*, vol. 97, No. 10, March 9, 1916.)—R. Philipp, a German engineer, has devised what might properly be termed a mincing machine which cuts into small bits all sorts of metal turnings, and in this way effects

substantial economies that materially improve the market value of this particular kind of scrap. In the first place, he made it possible to save in space something like 80 or 90 per cent., so that the waste materials, when ground up, occupy approximately about one-tenth the room ordinarily needed for turnings as they come from lathes. Owing to its reduced bulk and lowered storage charges it brings better prices from the purchaser. It can be readily freed of oil by means of centrifugal separators, and that iron and steel scrap in this form can be separated magnetically from other scrap material is an advantageous factor in its preparation for further use.

In general design it resembles the common type of vertical conical hopper grinder. If desired, a magnetic separator can be attached. The largest amount of scrap dealt with by one of the Philipp cutters was some 7700 pounds of manganese copper turnings disposed of in 20 minutes. A 25-horse-power direct-current motor was employed. It was found, after a six months' trial, that the entire cost of using the Philipp apparatus did not exceed 32 cents per ton of scrap cut up. But subsequent use proved that the average cost of the service per ton was less than 24 cents.

Road-building Rock Tests. ANON. (United States Department of Agriculture, Office of Information, March 17, 1916.)—Counties or communities intending to build water-bound macadam roads run considerable risk of failure unless they have the rock they are to use tested for hardness, toughness, and binding power. These are the qualities, in the opinion of the engineers of the Office of Public Roads and Rural Engineering, United States Department of Agriculture, which experience has shown to be most essential to the endurance of a road. The use of rock suited to withstand the wear of traffic is regarded as so important that the United States Department of Agriculture offers to test samples of road-building rock for any citizen free of charge, provided that the samples are sent prepaid and are submitted in accordance with definite printed instructions. These instructions will be mailed by the Office of Public Roads and Rural Engineering in that department to whoever requests a copy. When a community is considering using a local stone or other stone which has not already proved its durability on highway work, the highway supervisors would do well to secure a laboratory report from the Department. These laboratory tests are conducted with elaborate apparatus, and, in the case of untried rock, are the only practical safeguards against the employment of material that will wear out too quickly to prove a good investment.

Engineers having to do with road-building material, or road officials contemplating the establishment of a laboratory for testing the rock used on their highways, will find that Bulletin No. 347 contains full details as to the apparatus needed and the exact methods of procedure in the case of their tests, as well as those for determining the specific gravity and water-absorbent qualities of the rock.

Automatic Motor-driven Typewriter for Printing Form Letters. ANON. (*Electrical World*, vol. 67, No. 11, March 11, 1916.)—Form or circular letters, written on the ordinary duplicating machines with the name, address, and salutation "filled in" on the typewriter or from a name-plate, seldom receive the attention from the recipient that a letter entirely written on the typewriter does. The advent, therefore, of an automatic electrically-driven machine which, so far as results are concerned, produces a letter that bears all the marks of one printed by hand should prove of first importance as an office appliance.

A motor-driven typewriting machine, the operation of which is automatic and is controlled by a perforated "master sheet," is being made by the Hooven, Owens & Reutschler Company, of Hamilton, Ohio. A $\frac{1}{10}$-horse-power motor is utilized to operate the automatic mechanism. The master sheets are prepared on a perforating machine, which is equipped with an ordinary standard keyboard. The copy produced is in the form of perforations upon a roll of strong paper similar to the perforated rolls of the player-piano. The complete equipment consists of a standard typewriter of any special type and style desired, to which is connected the automatic operating device, and the perforating machine mounted on a separate stand. The typewriter can also be operated by hand when desired. The machine writes from 100 to 120 words per minute.

Calculation of Skin Effect in Strip Conductors. H. B. DWIGHT. (*Electrical World*, vol. 67, No. 11, March 11, 1916.)—The theory of the alternating-current skin effect of infinitely wide strips was published by Lord Rayleigh nearly thirty years ago, but the experimental observations in the A. I. E. E. paper of Messrs. Kennelly, Laws, and Pierce, last September, seem to have been the first publication of actual measurements on the subject. Those measurements showed that the skin-effect resistance ratios for ordinary sizes of copper strip are many times greater than those to be expected from the theory of infinitely wide strips.

The author collects the observations given in the A. I. E. E. paper, and shows that the skin-effect resistance ratios of these strips, up to frequencies of 5000 cycles, when plotted as ordinates against a certain specific quantity $\sqrt{f/R}$ as abscissas, where f is the impressed frequency and R the tabular linear resistance of the conductor in ohms per thousand feet, gives a curve which rapidly tends to a straight line. The corresponding curve and asymptotic straight line for round wires are already known. It is pointed out that, whereas the curve for round wires represents a definite formula, established both by measurement and by theory, the new curve for strips represents only an empirical result, based on certain concordant measurements, but not established as yet on a definite theory. The curves offered by Mr. Dwight, however, will, within their limitations, be very useful.

A New Process of Refining Nickel. ANON. (*The Iron Trade Review*, vol. lviii, No. 10, March 9, 1916.)—A new process of refining nickel has been discovered in Canada by which 100 pounds of ore can be converted into 50 pounds of metal in 48 hours. Prof. L. P. Burrows is the inventor of this new process, which seems likely to revolutionize the nickel industry. The process is also applicable to the treatment of other ores. By Professor Burrows's method there is no preliminary roasting. The ore, when mined, is crushed and placed in the refining apparatus, where it is subjected to a gaseous treatment for about five hours. After this it is smelted and refined to the finished alloy in the form of a very fine powder, being a very superior article for alloying steel. This powder equals about 75 per cent. of the ore. If desired, the powder can be reduced to the metallic form, producing about 50 per cent. in weight of the ore, entirely free from sulphur and eminently suitable as a high-grade metal for many purposes, as well as for alloying steel. The steel produced by this alloy has proved better than steel produced by a higher percentage of alloy as done by the old method. Professor Burrows has demonstrated that the immense iron deposits of the Laurentian range can be satisfactorily treated, and that the new process will result in the building up of enormous industries in the production of steel, and particularly the world's supply of nickel steel.

The Compressibility of Natural Gas at High Pressures. G. A. BURRELL and I. W. ROBERTSON. (United States Bureau of Mines, Technical Paper 131, February, 1916.)—In the course of its examination of samples of natural gas from many different gas fields through the country the Bureau of Mines has conducted various special researches in order to ascertain with exactness the composition or physical properties of certain of the samples or to determine the bearing of the facts on larger problems involved in the transportation and use of the gas. This paper treats of an investigation of the compressibility, at pressures up to 35.5 atmospheres, of the natural gas supplied to the city of Pittsburgh, and points out the bearing of the results on the measurement of natural gas at high pressures.

The natural gas used at Pittsburgh is found to contain 84 per cent. methane. The compressibility of methane has been determined by Amagat from pressures of 39 atmospheres to 290 atmospheres. From 39 atmospheres (his lowest observation) to 1 atmosphere approximate values have been derived by extrapolation. Methane is about 9 per cent. more compressible at 40 atmospheres and about 17 per cent. more compressible at 100 atmospheres than at 1 atmosphere. The compressibility of the gaseous constituents of natural gas, such as ethane, propane, and butane, has not been determined. These constituents deviate more from Boyle's law than does methane, and hence make natural gas more compressible than if it consisted of methane alone. The compressibility of the natural gas of Pittsburgh

is shown by manometer tests to differ from that of an ideal gas by as much as 15 per cent. at a pressure of 35.5 atmospheres.

The results are of practical value because, in measuring natural gas, it is the practice to assume that the product of the pressure by the volume is a constant. As to the application of these results, it may be noted that sometimes natural gas is measured at pressures as high as 40 atmospheres, and that many millions of cubic feet are measured at pressures of 20 to 30 atmospheres. In computing the volume of gas, the assumption is always made that Boyle's law applies; that is, that the product of pressure and volume is constant at all pressures. Hence, in measurements under high pressure, the error introduced is of great magnitude. For instance, suppose 100,000,000 cubic feet of gas a day are measured at 375 pounds. According to the tests, the gas is 11 per cent. more compressible at 375 pounds than at atmospheric pressure. This means that each day 11,000,000 more cubic feet of gas are measured than are supposed. If no correction is applied in measuring the gas, a distributing company that buys natural gas at high pressure and sells it at low pressure may sell much more gas than it pays for.

The Origin of the Watch. G. F. EBERHARD. (*The Metal Industry*, vol. 14, No. 3, March, 1916.)—We learn from books of record the first watches were made in the year 1500, in Nurenberg, Germany. They were made of iron, all parts, even the dials. Brass was substituted in 1530, and in 1550 watches began to come into vogue. In 1570, odd-shaped watches, hexagon and octagon shape, began to be fashioned. It was not until 1587 that the watch industry began in Switzerland.

The fuzee chain was invented by a Swiss by the name of Gruet in 1590. Up to this time a catgut cord was used. Watch-crystals of glass were first made in 1615. Enamelled dials were first made in 1635. The balance spring (known as the hair-spring) was first made in 1676. It is said they were made from hog bristles, and that is how the name "hair-spring" originated. The minute-hand device was first made in 1687, with its hour and minute wheels and cannon pinion which carries the minute hand. The first keyless watches were made in 1700. The compensating balance was invented in 1749. The duplex escapement was first made in 1750. The lever escapement, now so extensively used, was invented in the year 1776. Second hands were first used in 1780. Thin watches were first made in 1776. It will be noted that all important inventions for making watches were made in Europe.

The difficulty with European watch manufacturers was that one small factory would make wheels, and another staffs, and so on, by hand, with the result that, in some places, 34 small factories would make the 150 parts to be finally assembled, requiring an amount of hand work depending upon the skill of the workmen to secure accurate timekeeping qualities. American watch factories have de-

veloped the manufacture of watches so that all parts, including the cases, are made in one large factory with modern machinery, often specially designed for making the parts as nearly as possible in duplicate and interchangeable.

The first watches were made in the United States by Luther Goddard, of Shrewsbury, Mass., in 1812. He made two watches per week, and after completing about 500 watches he retired from business in 1817. About the same time a small watch factory was started in Worcester, Mass., which soon failed. In 1838 the first watches were made by machinery by James and Henry Pitkin, of Hartford, Conn. They produced about 800 watches and retired in 1841. In 1848 Aaron Dennison commenced to develop machinery, and, with E. Howard, his first watches were put on the market in 1853, under the name of "Boston Watch Company," making five watches per day. In 1854 Dennison moved to Waltham, and the company failed in 1857. In 1859 the Waltham watch industry was reorganized.

Several employees of the Waltham factory removed to Elgin, Ill., in 1865 and established the Elgin watch factory. Later the Rockford Watch Company and the Springfield Watch Company were started by employees who left Elgin. Ambrose Webster, who learned his trade as machinist and toolmaker in the Springfield Armory, Springfield, Mass., notable for fine machinery equipment and for doing accurate work, was for some years foreman in the Waltham factory, beginning in 1857. He left them in 1876 and started the American Watch Tool Company, which company furnished the machinery for a number of watch factories. Some failed in years following, resulting in the establishment of the Hamilton, Deuber, and South Bend watch factories.

A new era in the watch business began in 1890, when Robert H. Ingersoll developed the first guaranteed dollar watch, manufactured at Waterbury, Conn., at a rate of 15,000 per day. The success of the dollar watch led to the manufacture of higher grades. The Ingersoll-Trenton watch factory will soon reach the 1000 per day output of the new Ingersoll Reliance watch.

Aluminum Dust. G. H. CLEVENGER. (*Mining and Scientific Press*, vol. 112, No. 4, January 22, 1916).—In the mining industry aluminum dust is chiefly of interest as a precipitant of the precious metals in the cyanide process. It is also used as a reducing agent wherever a powerful metallic reducing agent is required, as, for example, in the production of carbon-free metals, particularly those difficult to reduce, or in the Goldschmidt process of welding (thermit) for producing *in situ* superheated molten iron or steel. Another use is as a "bronze powder" in the preparation of aluminum paint. Perhaps the most important use at the present time is in the manufacture of various explosives. This was first proposed by Escales, of Munich, in 1899, and in 1900 von Dahmen patented the use of aluminum, magnesium, or other light metal mixed with an oxidizing

agent. Ammonium nitrate was among the first used of such oxidizing agents. This explosive, called "ammonal," has given good results in mining and as a high explosive in shells. It has the advantage of being insensitive and very stable, as indicated by the fact that in Austria-Hungary shells filled with it were found good after ten years. Recently aluminum dust has been added to many other explosives. Other metallic powders, as, for example, magnesium, copper, zinc, iron, silicon, ferro-silicon, certain of the rare metals, and various alloys, are now used for a similar purpose. An example of the composition of a modern high explosive using aluminum dust is as follows: Ammonium nitrate, 45 parts; di- or tri-nitrotoluene, 1905 parts; aluminum dust, 45 parts. The aluminum dust is about 92 per cent. pure.

Aluminum dust is frequently adulterated with powders of other metals, particularly zinc and tin, and, at times, also with mica. The difficulty of manufacture accounts for the relatively high cost of the dust, which, in normal times, is almost double that of the metal in other forms. One method of manufacture involves the production of foil by a special system of rolling or combined rolling and hammering. The perfect foil is marketed in that form, while the imperfect foil, usually constituting 65 to 67 per cent. of the total, is comminuted in two series of special stamp mills, the finished product being separated by bolting and winnowing. The final operation is the polishing of the dust in a special device. Another method is to force gas and air into molten metal while it is setting, accompanied by vigorous mechanical stirring. The granules thus formed are powdered in special stamp mills or ball mills. The finely-ground dust is separated and polished as previously mentioned. In all the methods of making aluminum dust it is necessary to add stearine or some other wax to prevent the welding together of the fine particles during crushing.

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